GLENN L. MARTIN COMPANY,
Titan Missile Test Facilities
(Martin Marietta, Titan Missile Test Facilities)
Waterton Canyon Road and Colorado Highway 121
Vicinity of Lakewood
Jefferson County
Colorado

HAER No. CO-75

HAER
COLO
30-LAKWD.V,
2-

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

REDUCED MEASURED DRAWINCS

HISTORIC AMERICAN ENGINEERING RECORD
Rocky Mountain System Support Office
National Park Service
P.O. Box 25287
Denver, Colorado 80225-0287

HAER
COLO
30-LAKWD.V
2-

HISTORIC AMERICAN ENGINEERING RECORD
GLENN L. MARTIN COMPANY, TITAN MISSILE TEST FACILITIES
(Martin Marietta, Titan Missile Test Facilities)
HAER Number CO-75

Location:	The test facilities are located approximately 9.8 miles south of Lakewood, Jefferson County, Colorado, near the southern terminus of Colorado State Highway 75.
USGS 7.5 Minute Quads:	Indian Hills, Colorado, 1980. (Test Stands, Control Buildings) Littleton, Colorado, 1980. (Cold Flow Laboratory, Catch Basin)
UTM Coordinates:	Captive Test Stand D-1 13/489200/4372070 Captive Test Stand D-2 13/488785/4372850 Captive Test Stand D-3 13/488850/4373495 Captive Test Stand D-4 13/488495/4373640 Control Building A 13/488960/4372010 Control Building B 13/488610/4373400 Cold Flow Laboratory 13/489500/4373490 Catch Basin 13/489970/4373120
Dates of Construction:	1956-1959; Altered 1960-61
Present Owners:	United States Air Force
Present Use:	The four Captive Test Stands and Control Building B are abandoned and slated for demolition. Control Building A serves as a Records Retention Center for Martin Marietta. The Cold Flow Laboratory is now the company's Engineering Propulsion Laboratory.
Significance:	When the Glenn L. Martin Company completed its new Titan missile plant near Denver in the late 1950s, the Air Force described it as the first completely integrated missile facility "in the western world, and probably the entire world." Although the plant included extensive facilities for project administration, engineering, and production, its most unusual feature was a "backyard" testing complex, consisting of four enormous captive test stands where the completed missiles' rocket engines could be test fired under controlled conditions prior to launch. These facilities played a crucial role in the development of the Titan I and Titan II intercontinental ballistic missiles, the largest and most powerful weapons in the nation's nuclear deterrent force.
Historians:	John F. Lauber and Jeffrey A. Hess, December 1993 Hess, Roise and Company, Minneapolis

This Historic American Engineering Record study describes the Titan intercontinental ballistic missile test facilities at the Glenn L. Martin Company, Jefferson County, Colorado. These facilities have been determined eligible for listing on the National Register of Historic Places. The recordation is the result of an interagency agreement between the National Park Service and the Department of the Air Force, and was completed in conjunction with environmental mitigation of the site by the Air Force.[1]

INTRODUCTION

On 18 November 1955, a weekly newspaper published in the Denver suburb of Littleton reported that the Glenn L. Martin Company, a Baltimore-based aircraft manufacturer, was planning to buy "up to 10,000 acres" of ranchland southwest of the city in order to build "an Air Force guided-missile plant."[2] The front-page story carried a lengthy discussion of the real estate transactions and water rights negotiations that would have to be completed before the deal could go through, but provided little information about the exact nature of the proposed plant or its products. It was evident that reporters had conducted extensive interviews with local functionaries, land agents, and property owners. What was missing was an official statement from the United States Air Force. This omission was noted, but not explained, in the last column:

> [The Secretary of the Air Force] was supposed to have released the story about the Littleton plant Tuesday after declining to give details last Saturday. . . .

---

[1] Jeffrey A. Hess, of Hess Roise and Company, Minneapolis, Minnesota, was principal investigator for the project. John F. Lauber, a historian with Hess Roise, researched and wrote the narrative. Clayton B. Fraser, of Fraserdesign, Loveland, Colorado, prepared measured drawings of the facilities. Robert Lyon of the National Park Service, Rocky Mountain Regional Office, Denver, was project photographer. Dr. Michael G. Schene, a historian with the Rocky Mountain Regional Office, served as project administrator.

[2] "Factory 9 Times Size of Heco Slated Southwest of Littleton," Littleton Independent, 18 November 1955.

The story was held up again, and so it is being pieced together in Littleton by hearsay.

The Martin Company, for its part, was in no hurry to fill in the details. On 28 November, Martin issued a carefully worded press release stating that it was indeed planning to build "a new aircraft plant" near Denver.[3] When the Denver Post attempted to embellish the story by suggesting that the plant might be used to manufacture "an intercontinental guided missile . . . capable of carrying an atomic warhead," the company "declined to specify what products would be made in Denver."[3]

The Air Force continued its silence. When Aviation Week magazine reiterated the Post's contention that the Denver plant would be used to build a long-range nuclear missile, Air Force officials "said that no contract has been signed with Martin for production of an [intercontinental missile] . . . and refused to comment on whether negotiations were in progress."[4]

Despite the official reticence about the purpose of the new plant, one thing was certain. The facility, which the Chamber of Commerce described as "the largest development project in Denver history," was good news for the local economy. Materials for the installation, which was initially expected to cover 500,000 square feet and cost $6

---

[3] Warren Lowe, "Martin Aircraft to Build Plant Near Denver," Rocky Mountain News, 29 November 1955. Future citations of the Rocky Mountain News will be identified as RMN, with appropriate titles and dates.

[3] Robert Byers, "Denver Gets Missile Plant," Denver Post, 28 November 1955. Henceforth, the Denver Post will be cited as DP, with appropriate titles and dates.

[4] "Martin to Build New Plant Near Denver," Aviation Week 63 (5 December 1955): 16.

million, would be purchased locally whenever possible. Nearly 10,000 area construction workers would be needed immediately to help build the new factory. When it was finished, Martin anticipated that the plant would provide full-time work for 5,000 employees, many of whom would be recruited from the Denver area. According to one newspaper account, this would "make the Martin Company Denver's second largest private employer and would add $25 million a year to the area's payroll."[5]

Site work for the new plant began in January 1956, and ground was broken for the first building in early February. Even after the construction had begun, military and company officials steadfastly evaded all inquiries about the precise purpose of the facility.

Finally, on 21 March, the word came down from Washington. In a speech delivered to a meeting of the Aviation Writers' Association, Secretary of the Air Force Donald A. Quarles "confirmed that the Glenn L. Martin plant southwest of Denver is gearing to produce the mightiest weapon in the nation's arsenal -- the intercontinental ballistic missile." He also gave the project a name. According to Quarles, the new, "ultra long-range rocket" would be called the Titan.[6]

"WHAT'S A MISSILE?"

During the spring of 1956, 239 employees from the Martin Company's home office in Baltimore transferred to Denver, where they established temporary headquarters on the

---

[5] Lowe, "Martin Aircraft to Build Plant Near Denver," RMN, 29 November 1955.

[6] "Martin Plant to Make Mightiest of Missiles," RMN, 22 March 1956.

second floor of the Shell Oil Company building downtown. This advance crew was responsible for overseeing construction of the new plant and for hiring the people who would work there. According to one member of the original contingent, the task proved to be an immense challenge: "In those days, you would get people off the street, say you want them to build a missile, and they would say, 'What's a missile?'"[7]

It was a reasonable question. In the mid-1950s, the intercontinental ballistic missile was a technological vision that existed only in the imaginations of a few scientists and military planners. Consequently, when Newsweek magazine attempted to describe the yet-to-be-built ballistic missile to its readers in 1955, it had to start the description with a disclaimer:

> No one really knows what the intercontinental ballistic missile will look like or how it will work. . . . It will be very large, perhaps 135 feet tall. . . . It will be very heavy, weighing perhaps half a million pounds, with 80 percent of the weight fuel. It will be very fast, traveling at a rate somewhere between 8,000 and 15,000 miles an hour. It will be built in sections, and only the warhead will arrive at the target; the other sections will fall off on the way. It will have a range of 5,000 miles. And it will be armed with a thermonuclear charge. Taking off vertically from a special platform, the IBM [Intercontinental Ballistic Missile] will thunder skyward under the impetus of multiple rocket motors.[8]

To a great extent, it was the rocket motor that made the intercontinental ballistic missile possible. "In fact," wrote Air Force propulsion expert Edward Hall in 1957, "the long-range ballistic missiles are so intimately tied up with rocket propulsion systems that

---

[7] A Martin Company history attributes the comment to Beal Teague; see Martin Marietta Aerospace: 30 Years of Progress (Denver: The Company, 1986), n.p.

[8] "Push-Button Defense?" Newsweek 45 (2 May 1955): 27.

frequently the terms missile and rocket are used interchangeably."[9] Only a rocket engine was powerful enough to lift such a ponderous projectile off the ground and hurl it into space at supersonic speed. Because a rocket carried its own supply of oxygen, it could continue to operate outside the earth's atmosphere. This allowed the missile to fly high enough to establish the ballistic trajectory that would take it to its target halfway around the world.

Historians generally trace the origins of rocketry to China. By the beginning of the twelfth century, the Chinese had developed simple solid-fueled rockets consisting of little more than gunpowder-packed paper tubes attached to wooden guide shafts. The technology was still basically the same seven hundred years later when the British deployed gunpowder rockets against American troops in the War of 1812. Although the U.S. Army developed a slightly improved version for use as a long-range weapon during the Civil War, rockets remained largely a curiosity through the end of the nineteenth century -- more likely to appear at a Fourth of July celebration or a county fair than on the field of battle.[10]

At the beginning of the twentieth century, Dr. Robert Goddard, a taciturn physics professor at Clark University in Worcester, Massachusetts, began a series of experiments that he hoped would eventually lead to more serious applications for rockets. By the time the United States entered World War I, Goddard had been researching the topic for nearly ten years, and had made considerable progress in the field. In his administrative history of the American missile program, Air Force historian Jacob Neufeld notes that in 1918:

---

[9] Edward N. Hall, "Air Force Missile Experience," Air University Quarterly Review 9 (Summer 1957): 27.

[10] For a concise history of rocket technology, see George P. Sutton, "Rockets and Missiles," Academic American Encyclopedia (Danbury, CT: Grolier, Incorporated, 1989), 251-60.

> [Goddard] proposed to develop rockets for the Army and Navy. On November 6, at the Aberdeen Proving Ground, Maryland, he demonstrated successfully a series of tube-launched, solid-fueled rockets that could be fired from the ground, or from airplanes. But, five days later, the war ended and with it the military's interest in rockets.[11]

Goddard continued his experiments after the war, and in 1926, he successfully launched the world's first liquid-fueled rocket from a farm near Auburn, Massachusetts. This unlikely-looking contraption, assembled from materials purchased at a local hardware store and powered by a mixture of gasoline and liquid oxygen, rose 41 feet into the air and traveled less than 200 feet from its starting point before crashing back to earth. The entire flight lasted less than three seconds. Within a few years, however, Goddard's test flights had become considerably more impressive:

> In 1929, the blast of one of his rockets . . . attracted the press and the fire marshal to the secluded farm in Auburn. The reporters said the professor was trying to fly up to the moon, which he wasn't, and that one of his rockets had blown up, which it hadn't. The marshal . . . simply called the rocket a fire hazard, which it was, and ruled it out of the sovereign state of Massachusetts.[12]

Shortly after this incident, Goddard moved his laboratory to Roswell, New Mexico, where he sustained his research with a modest grant from the Guggenheim Foundation. Over the next decade and a half, he was issued patents for more than 200 improvements in rocket technology. Nonetheless, few Americans outside the patent office knew anything about Goddard's work. Scientists and military officers in Germany, however, had been paying close attention to the professor's experiments, and during the 1930s, they began to build an

---

[11] Jacob Neufeld, The Development of Ballistic Missiles in the United States Air Force, 1945-1960 (Washington: Office of Air Force History, United States Air Force, 1990), 38.

[12] Milton Lehman, This High Man (New York: Pyramid Books, 1970), 17.

arsenal based on his research. As Neufeld explains:

> Prohibited under the terms of the Versailles Treaty from producing conventional weapons, the German Army turned its attention to rockets as a means of extending long-range artillery. . . . Between 1937 and 1938 the Germans built the large experimental rocket station at Peenemünde on the Baltic Sea. Here they developed and tested the A-4 model . . . , better known as the V-2. . . . Standing 46 feet high and 5 feet in diameter, the 14-ton rocket flew about 200 miles and delivered a 1,650-pound amatol warhead. . . . On October 3, 1942, after two unsuccessful launch attempts, the V-2 completed a flight test of 120 miles and became the world's first long-range ballistic missile.[13]

Between September 1944 and May 1945, Nazi troops fired nearly four thousand V-2 missiles at targets in England and continental Europe. These missiles were extraordinarily expensive -- especially since more than half missed their targets altogether. Yet during their eight-month stint on the battlefield, these early ICBMs clearly demonstrated one extremely important characteristic: Once they had left their launch pads, there was virtually no way to stop them. Nearly ten years after the war ended, Secretary of the Air Force Harold E. Talbott was still impressed by this capability:

> Remember this: the speed of the Germans' V-2 ballistic missile as it plunged down on its target was 3,500 miles an hour. Can you imagine intercepting it? Two of us might as well stand at opposite ends of a hall and pitch needles at each other in the hope that the needles might collide.[14]

By 1945, the intercontinental ballistic missile had emerged as a promising, though still imperfect, military technology. The liquid-fueled rocket engine had made it possible. But it was another product of World War II that would eventually make it practical.

---

[13] Neufeld, Development of Ballistic Missiles, 40-41.

[14] Talbott is quoted in "Enter the IBM," Time 64 (6 December 1954): 28.

THE BOMB

Shortly before sunrise on 16 July 1945, a technician named Donald Hornig stood inside a crowded bunker in the middle of the New Mexico desert. At precisely 5:29:45 A.M., he reached out and flipped a switch on the control panel in front of him, sending a charge of electricity through cables attached to a steel tower nearly ten miles away. The result was literally beyond imagination:

> A pinprick of brilliant light punctured the darkness, spurted upward in a flaming jet, then spilled into a dazzling cloche of fire that bleached the desert to a ghastly white. . . . For a fraction of a second the light in that bell-shaped fire mass was greater than any ever produced before on earth. Its intensity was such that it could have been seen from another planet. The temperature at its center was four times that at the center of the sun. . . . The pressure, caving in the ground beneath, was over 100 billion atmospheres, the most ever to occur at the earth's surface. The radioactivity emitted was equal to one million times that of the world's total radium supply.[15]

When the firestorm abated, a team of white-suited scientists climbed into tanks and drove out to where the tower had been. In its place they found a glassy green crater, 1200 feet across and 25 feet deep. This newly created monument, code-named Trinity, marked the birthplace of the atomic bomb.

In the months prior to the Trinity test, a number of leading scientists had urged Roosevelt, and then his successor Truman, to share the secrets of the atomic bomb with the Soviet Union. England had collaborated on the project from its inception. These advisors argued that if the United States unleashed the bomb without informing its other major ally, the Soviets would inevitably see the act as a challenge, and would feel compelled to develop

---

[15] Langston Lamont, Day of Trinity (New York: Atheneum, 1965), 235-236. See also Fred Inglis, The Cruel Peace (N.p.: Basic Books, 1991), 40-41.

nuclear weapons of their own. As each nation struggled to maintain its atomic advantage, the world would be plunged into an uncontrollable arms race.[16]

Like Roosevelt before him, Truman did not wish to forfeit what might be a potentially useful strategic advantage over the Russians. In this, he was supported by his newly appointed Secretary of State James Byrnes, who believed in forging an American foreign policy based on military superiority. At the time of the explosion, Truman was in Potsdam, Germany, for a meeting with Winston Churchill and Joseph Stalin to map the boundaries of the postwar world. Hoping that the Trinity blast would aid negotiations with the Soviets, he was heard to say: "If it explodes as I think it will, I'll certainly have a hammer on those boys."[17]

Within a few weeks of the Trinity test, the United States had demonstrated the apocalyptic power of nuclear weapons two more times, first at Hiroshima and then at Nagasaki. These demonstrations ended the war and seared the names of the two Japanese cities into the world's collective memory.

U.S. government statements issued immediately after the bombings mentioned nothing about a national quest for strategic superiority. In August 1945, President Truman summarized the official position in a radio address: "We have used [the bomb] in order to shorten the agony of war, in order to save the lives of thousands and thousands of young

---

[16] For a thorough discussion of the debate between the scientists and the policymakers, see Martin J. Sherwin, "The Atomic Bomb and the Origins of the Cold War: U.S. Atomic-Energy Policy and Diplomacy, 1941-45," American Historical Review 78 (October 1973): 945-68.

[17] Lamont, Trinity, 228; on Byrnes, see Inglis, Cruel Peace, 44.

Americans."[18] But when a member of Great Britain's Advisory Committee on Atomic Energy reexamined these events three years later, he saw things another way: "The dropping of the atomic bomb was not so much the last military act of the second World War, as the first major operation of the cold diplomatic war with Russia now in progress."[19]

"A SHOTGUN MARRIAGE"

"The cold war started a long time before the Second World War stopped," observes Fred Inglis in the introduction to his study of everyday life during the cold war era.[20] German historian Wilifred Loth elaborates:

> The relationship of the Soviet state with American society had been ambivalent since the October [1917] Revolution. On the Soviet side, people had marvelled at the radical democratic tradition of the USA and the high performance of its industrial economy, while at the same time fearing the latent aggressiveness and ever greater power of capitalism. On the American side, there was both enthusiasm about the modernisation of the former Russian feudal society and horror at the methods of this modernisation and at the prospect of them being transferred to the Western world."[21]

Immediately following the First World War, the U.S. government worked assiduously to eliminate the threat of communism, first by sending American troops to Russia as part of an Allied attempt to overthrow Lenin, and then by isolating the newly formed Bolshevik state

---

[18] Truman is quoted in John M. Blum, et al, The National Experience (New York: Harcourt Brace Jovanovich, 1973), 702.

[19] P. M. S. Blackett, Fear, War, and the Bomb (New York: McGraw Hill Book Company, Incorporated, 1948), 139.

[20] Inglis, Cruel Peace, xvii.

[21] Wilifred Loth, The Division of the World, 1941-1955 (New York: St. Martin's Press, 1988), 27.

from the rest of the world. During the 1920s, the latter effort was thwarted in part by American corporations, which saw the Soviet Union less as an ideological demon than as a vast, untapped market. As western enterprises such as Westinghouse, General Electric, and the Ford Motor Company began to do business in Russia, the two politically divergent countries became indisputably linked by economics -- a fact which the U.S. grudgingly acknowledged in 1933 by granting diplomatic recognition to the 16-year-old Soviet government.[22]

Despite this conciliatory gesture, Soviet-American relations worsened steadily during the remainder of the decade as Stalin completed his ruthless ascent to power and the United States repeatedly refused Soviet requests for help in halting Japanese incursions into its territory. American distrust reached a high point in 1939, when the Soviet Union signed a non-aggression pact with Nazi Germany in a last-ditch attempt to protect its borders from invasion. Nonetheless, the United States did come to Russia's aid when Hitler reneged on his agreement and sent troops swarming into the Soviet Union in June 1941. But as diplomatic historian Walter LaFeber has observed, the Roosevelt Administration entered the alliance with about as much enthusiasm as the groom at a "shotgun marriage":

> The State Department debated for twenty-four hours before issuing an announcement that condemned the Soviet view of religion, declared that 'communistic dictatorship' was as intolerable as 'Nazi dictatorship,' said nothing good about the Russians, but concluded they must be helped since Hitler posed the larger threat.[23]

---

[22] Much of the discussion in this section is based on Walter LaFeber, America, Russia, and the Cold War, 1945-1975 (New York: John Wiley and Sons, Incorporated, 1976), 1-7.

[23] LaFeber, America, Russia and the Cold War, 6.

For the next four years, the exigencies of the battlefield compelled the postponement of postwar questions. In the words of historian Arthur Schlesinger, Jr., Allied leaders became "addicts of improvisation . . . . Like Eliza, they leaped from one cake of ice to the next in the effort to reach the other side of the river."[24] But as the threat of Naziism receded, the prewar rancor quickly reemerged. When the Allies began to apportion control of Europe in 1945, the Soviet Union immediately attempted to surround itself with a "buffer zone" that included the Baltic States as well as parts of Poland, Finland, and Rumania. The United States saw this move as merely the most recent manifestation of a deep-seated, almost instinctive Russian "expansionism."

At the same time, the United States began to reexamine Soviet communism through a new psychological lens that threw the atrocities of Hitler and Stalin into overlapping focus. Discarding traditional dichotomies of "fascist" and "bolshevik," "left" and "right," a new generation of political theorists argued that Naziism and Stalinism were similar manifestations of a new modern evil called "totalitarianism," which was more a method of organizing society than a body of beliefs. According to Hannah Arendt, who was responsible for the fullest elaboration of the idea, a totalitarian system was "international in organization, all-comprehensive in its ideological scope, and global in its political aspiration."[25] As old American fears received new intellectual justifications, "the Russian

---

[24] Arthur Schlesinger, Jr., "Origins of the Cold War," Foreign Affairs 46 (October 1967): 26.

[25] Hannah Arendt, The Origins of Totalitarianism (New York: Harcourt, Brace & World, Inc., 1966), 389.

ally slipped easily into the space vacated by the Nazi enemy, and fitted it comfortably."[26]

In 1946, George Kennan, Chargé d' Affaires at the U.S. Embassy in Moscow, dispatched a lengthy telegram to the State Department in which he articulated what was to become the official, postwar American view of the Soviet Union:

> We have [in the Soviet Union] a political force committed fanatically to the belief that with [the] U.S. there can be no permanent modus vivendi, that it is desirable and necessary that the internal harmony of our society be disrupted, our traditional way of life be destroyed, the international authority of our state be broken, if Soviet power is to be secure.[27]

A year later, in one of the most influential articles of the postwar period, Kennan pseudonymously described the path that the United States should follow in its dealings with the Russians: "It is clear that the main element of any United States policy toward the Soviet Union must be that of a long-term, patient, but firm and vigilant containment of Russian expansive tendencies."[28]

"A BARGAIN-BASEMENT DEFENSE"

After World War II, the Soviet Union undertook a massive effort to rebuild its much-depleted army and replenish its supply of conventional weapons. War-weary taxpayers in the United States, however, were unwilling to pour more money into Defense Department coffers. "Americans had sacrificed during the war," explains LaFeber. "Now they wanted

---

[26] Inglis, Cruel Peace, 36.

[27] George Kennan, "The Kennan 'Long Telegram,'" Origins of the Cold War (Washington: United States Institute of Peace, 1991), 28.

[28] "X" [George Kennan], "The Sources of Soviet Conduct," Foreign Affairs 25 (July 1947): 575.

to spend on themselves."[29] Consequently, the United States took advantage of its position as sole proprietor of the atomic bomb to pursue what social historian David Halberstam has called "a bargain-basement defense policy."[30]

The U.S. began to demobilize its conventional forces shortly after the Japanese surrender in August 1945. By October the process was happening so fast that Harry Truman described it as "not so much a demobilization as a disintegration of the armed forces."[31] Drastic spending cuts over the next few years led Secretary of Defense James Forrestal to lament in 1948 that "the only balance . . . we have against the overwhelming manpower of the Russians, and therefore the chief deterrent to war, is the threat of . . . immediate retaliation with the atomic bomb."[32]

Despite Forrestal's apparent displeasure with his shrinking arsenal, most American policy makers still considered that the bomb provided the United States with a substantial advantage over the Soviets. The decision to demilitarize was based on a widespread belief that the nation's nuclear monopoly guaranteed invincibility. No enemy would risk annihilation by attacking the country that controlled the ultimate weapon. America's feelings of invulnerability also were reinforced by a general belief in the ineptitude of Soviet technology. Even among American scientists, a joke was current "that the Russians could

[29] LaFeber, America, Russia, and the Cold War, 44-45.

[30] David Halberstam, The Fifties (New York: Villard Books, 1993), 27.

[31] As quoted in Halberstam, 27.

[32] As quoted in Edmund Beard, Developing the ICBM (New York: Columbia University Press, 1976), 80.

not surreptitiously introduce nuclear bombs in suitcases into the United States because they had not yet been able to perfect a suitcase."[33]

According to historian David Rosenberg, however, America's sense of nuclear omnipotence was not entirely justified by the facts. The American bomb was indeed all-mighty, but the country's stockpile was extremely limited and the weapon's deployment quite difficult:

> There were only two weapons in the stockpile at the end of 1945, nine in July 1946, thirteen in July 1947, and fifty in July 1948. None of these weapons was assembled. They were all Mark 3 'Fat Man' implosion bombs, which weighed 10,000 pounds . . . and took 39 men over two days to assemble. Because the bombs were so large and heavy, they could only be loaded on their bombers by installing a special hoist in a twelve foot by fourteen foot by eight foot deep pit, trundling the bomb into the pit, rolling the aircraft over it, and then hoisting the weapon into the specially modified bomb bay. Through 1948, there were only about 30 B-29s in the Strategic Air Command modified to drop atomic bombs, all in the 509th Bomb Group based in Roswell, New Mexico.[34]

While the United States had been building this unwieldy arsenal, the much-demeaned Soviet scientists had also been busy. In August 1949, an American reconnaissance plane over Asia picked up traces of radioactivity in the atmosphere. As scientific analysis overcame initial disbelief, Washington officials came to the unhappy conclusion that the Soviet Union, without fanfare, had recently exploded its own atomic bomb.[35]

---

[33] Halberstam, The Fifties, 25.

[34] David Alan Rosenberg, "The Origins of Overkill," International Security 7 (Spring 1983): 14-15.

[35] Lamont, Trinity, 280.

"A BIGGER BANG FOR THE BUCK"

The Soviet nuclear test did not completely undermine American complacency. Shortly after the Russian success, General Omar Bradley, chairman of the Joint Chiefs of Staff, wrote that "as long as America retains (as it can) a tremendous advantage in A-bomb quantity, quality, and deliverability, the deterrent effect of the bomb will continue."[36] Bradley's optimism was probably justified. As Phillip Bobbit has observed in his 1988 study of the history of nuclear strategy: "It was absurd to postulate a Russian intercontinental surprise attack even with atomic weapons in 1950; the range of Soviet bombers, their number and the limitations of the fission bomb made such a strike implausible."[37]

But Bobbitt also points out that within four years the situation "had utterly changed." A few months after the advent of the Soviet A-bomb, the United States initiated a frantic effort to develop a so-called "super bomb," a thermonuclear weapon which would use a small atomic trigger to initiate a fusion reaction in hydrogen isotopes. Such a weapon was theoretically capable of producing an explosion hundreds of times more powerful than that of the atomic bomb, and its possession would clearly reestablish America's nuclear superiority. Nonetheless, as the research got under way, J. Robert Oppenheimer, who had spearheaded the effort to develop the American A-bomb, expressed some doubts about the new device: "I am not sure the miserable thing will work nor that it can be gotten to the target except by ox-

---

[36] As quoted in Samuel F. Wells, Jr., "The Origins of Massive Retaliation," Political Science Quarterly 96 (Spring 1981): 47.

[37] Phillip Bobbitt, Democracy and Deterrence (New York: St. Martin's Press, 1988), 27.

cart."[38]

Scientists at Los Alamos National Laboratory worked on the project for nearly two years. Finally, in November 1952, they put the "super" to the test. Wielding the force of twelve megatons of TNT, the new bomb wiped a small South Pacific island named Eniwetok off the face of the earth. Recalling the power of the Eniwetok explosion a few years later, Winston Churchill offered a somber assessment:

> There is an immense gulf between the atomic and hydrogen bombs. The atomic bomb, with all its terrors, did not carry us outside the scope of human control or manageable events . . . [but with the coming] of the hydrogen bomb, the entire foundation of human affairs was revolutionized, and mankind placed in a situation both measureless and laden with doom.[39]

At the time of the test, American Secretary of Defense Charles Wilson was more prosaic, but in his own way, equally accurate. The H-bomb, he explained, would give the United States "a bigger bang for the buck."[40]

The American H-bomb made it clear that the world was witnessing a nuclear arms race, and the Soviet Union kept pace. On 8 August 1953, the Soviets successfully tested a hydrogen bomb of their own. The mere fact of the explosion was unsettling enough for American military analysts, who tended to believe that the Russians were still years away from the event. Its scientific sophistication, however, was absolutely startling. The American H-bomb was not yet a practical weapon. It required a massive refrigeration

---

[38] As quoted in Peter Lewis, The Fifties (London: Cupid Press, 1989), 86.

[39] Quoted in Bobbitt, Democracy and Deterrence, 26-27. The words in brackets were added by Bobbitt.

[40] Wilson is quoted in Lewis, The Fifties, 89.

system that was too heavy for rocket delivery and even challenged the carrying capability of the country's largest bomber. But radioactive fallout from the Russian explosion contained traces of lithium, a rare metal which theoretically could eliminate the need for refrigeration. The implication was that the Soviet Union had developed an H-bomb that conceivably could fit into a ballistic missile.[41]

A PROJECT OF THE HIGHEST PRIORITY

In 1946, Bernard Brodie, a Yale professor of international relations who would soon become one of the nation's most respected analysts of nuclear military warfare, prefaced a lengthy discussion of the German V-2 missile by observing that "the atomic bomb . . . places an extraordinary military premium upon the development of new types of carriers." During World War II, said Brodie, the Germans had attempted to transform military strategy through the deployment of the V-2. But the missile's high cost, limited destructive power, and consistent inability to reach its intended targets severely constrained its usefulness. In the final analysis, "the side enjoying command of the air had in the airplane a much more economical and longer-range instrument for inflicting damage on [the] enemy . . . than was available in the rocket." At Hiroshima and Nagasaki, however, the economics of warfare truly changed:

> The power of the new bomb completely alters the considerations which previously governed the choice of vehicles. . . . A rocket far more elaborate and expensive than the V-2 . . . is an exceptionally cheap means of bombarding a country if it can carry

---

[41] Kaplan, Wizards, 112.

> in its nose an atomic bomb. The relative inaccuracy of aim . . . is of much diminished consequence when the radius of destruction is measured in miles rather than yards.[42]

Brodie's point was not lost on American military planners. According to ballistic missile historian Robert Perry, "an ICBM was among the several basic new weapons urgently recommended during the first postwar analysis of United States military needs." During the next few years, the Army, Navy and the newly created Air Force all initiated efforts to develop long-range missiles.[43] But as Perry points out, proponents of these projects were often "subjected to the derision of leading civilian scientists," who seemed to feel that, given the sad state of Soviet technology, "a genuine need for an ICBM" would not develop for at least "two or three decades." There were logistical obstacles as well:

> To have undertaken a serious ballistic missile program in the immediate postwar years would have required a very substantial investment in dollars and skilled manpower. Neither was among the resources of the military services in the half-decade between 1945 and 1950. Additionally, the time-tested 'logical sequence' approach to weaponry innovations appeared to require perfection of jet aircraft, moderate-range . . . missiles, and improved nuclear warheads before undertaking development of such visionary devices as intercontinental rocket missiles. . . . Faced with the hostile skepticism of respected scientific authority, the services discreetly shelved their plans for ballistic missiles and concentrated attention on less demanding programs.[44]

The Russian H-bomb explosion of 1953 effectively silenced the critics. It not only

---

[42] Bernard Brodie, "War in the Atomic Age," The Absolute Weapon (New York: Harcourt, Brace, and Company, 1946), 34-35.

[43] Robert L. Perry, "The Atlas, Thor, and Titan," Technology and Culture 4 (Fall 1963): 466. The Air Force was established as an independent branch of the armed forces on 26 July 1947. Prior to that date, it operated as a subdivision of the Army.

[44] Perry, "Atlas, Thor, and Titan," 467.

revived the dormant American missile program, but instilled in it a tremendous sense of urgency. The RAND Corporation -- an independent, but largely government-funded research institute -- played a leading role in reevaluating the feasibility and importance of the ICBM in light of the recent breakthroughs in thermonuclear technology. Its study was headed by Dr. Bruno Augenstein, a physicist who firmly believed that "if the Soviet Union beat the United States in a race for the ICBM, the consequences would be catastrophic."[45]

At about the same time, Trevor Gardner, the Air Force Secretary's Special Assistant for Research and Development, was assembling a committee of eminent scientists under the leadership of Dr. John von Neuman, a brilliant Princeton University mathematician who had invented the strategic analysis of social conflict known as "game theory." Von Neuman's group, code-named the "Teapot Committee," was ordered to investigate "the impact of the thermonuclear [bomb] on the development of strategic missiles and the possibility that the Soviet Union might be somewhat ahead of the United States."[46]

The RAND and Teapot Committee reports were released two days apart in February 1954. Both studies had reached essentially the same conclusions: The recent advances in thermonuclear weapons technology indicated that it would soon be possible to build a warhead combining light weight with unprecedented destructive power. Such a warhead

---

[45] Kaplan, Wizards, 112-13.

[46] Quoted in Dennis J. Stanley and John J. Weaver, "An Air Force Command for R & D, 1949-1976: The History of ARDC/AFSC," Office of History, Headquarters, Air Force Systems Command, n.d., page 22. TMs [photocopy]. This manuscript is included in the archives of the United States Air Force Historical Research Agency, Maxwell AFB, Montgomery, AL, document K243.04-39. Hereafter, materials from this collection will be cited as HRA, with appropriate locators.

would make an ICBM practical. Furthermore, an ICBM "could be developed and deployed early enough to counter the pending Soviet threat _if_ exceptional talents, adequate funds, and new management techniques suited to the urgency of the situation were authorized."[47]

The Air Force responded quickly. By mid-May 1954, officials had devised an ICBM development plan and made it the Air Force's top priority. At the end of June, General Thomas D. White, Air Force Vice Chief of Staff, formally directed the Air Research and Development Command "to proceed with the development of an ICBM at the highest speed possible, limited only by the advancement of technology in the various fields concerned."[48] The Research and Development Command immediately established a special project office to administer the program, assigning it "sole responsibility for the . . . research, development, test and production leading to a successful intercontinental ballistic missile system."[49] The agency was to be headquartered on the West Coast and would be called the Western Development Division. According to one writer, "the organization was so secretive that its very initials, WDD, were classified beyond top secret."[50]

---

[47] Perry, "Atlas, Thor, and Titan," 468.

[48] "Air Force Ballistic Missile Test Program," 1957, page 1. TMs [photocopy]. This manuscript is included in the archives of the Ballistic Missile Organization History Office, Norton AFB, San Bernardino, CA, in Box L-1. Henceforth, materials from this collection will be cited as BMO, followed by appropriate locators.

[49] Ernest G. Schwiebert, _A History of the U. S. Air Force Ballistic Missiles_ (New York, Frederick A. Praeger, 1965), 79. Dr. Schwiebert wrote this book while serving as Command Historian for the Air Research and Development Command.

[50] Kaplan, _Wizards_, 116. The Western Development Division was renamed several times. In 1957, the agency was redesignated the Air Force Ballistic Missile Division (AFBMD). In 1961 the agency moved into new quarters at Norton Air Force Base, where it was reorganized as the Ballistic Systems Division (BSD). The name was changed again in 1967, when BSD became part of the Space and Missile Systems Organization (SAMSO). Since 1979, the agency has functioned under the titles "Ballistic Missile Office" and "Ballistic Missile Organization," both

A newly promoted, 43-year-old brigadier general named Bernard A. Schriever was selected to direct the new agency. According to the New York Times, Schriever was "a model of informality [who] gives the impression that he has seen a lot of Jimmy Stewart films."[51] But he also had some credentials pertaining more directly to his new task. Besides a graduate degree in mechanical engineering from Stanford, he possessed extensive practical knowledge of aircraft gleaned from more than twenty years as a pilot. Air Force officials "evidently believed that this young officer would be unconventional enough to find new methods of operation, to short-circuit official red tape and circumvent bureaucratic meddling, and to break through the barriers that stood in the way of the successful completion of the missile program."[52]

On 5 August 1954, General Schriever and a small group of military officers converged on an empty parochial school in the Los Angeles suburb of Inglewood. To avoid arousing the curiosity of nearby residents, the officers had been instructed to leave their uniforms at home and to arrive at their new headquarters in civilian clothes. A journalist later described what they found when they got there:

> No sign identified the white schoolhouse as the Western Development Division. . . . The windows were frosted and heavily barred. All outside doors, except one, were locked. The only entrance was across a chain-link fenced parking lot. A security guard manned the door. . . . Some of the old-timers recall . . . the comment of the schoolboy who was sauntering by the school building. Eying the frosted glass and

---

represented by the acronym "BMO." Throughout this study, the agency is referred to as the Western Development Division (WDD).

[51] Quoted in Neufeld, Development of Ballistic Missiles, 108.

[52] Schwiebert, History of USAF Ballistic Missiles, 78.

steel-barred windows, he said to a chum, 'Boy am I glad I don't go to school here.'[53]

In this inconspicuous but carefully secured setting, the handpicked staff of the Western Development Division began organizing the effort to build the nation's first ICBM. Fortunately, they did not have to start entirely from scratch.

PROJECT ATLAS

By the time General Schriever and his associates arrived in Inglewood, one defense contractor had already been working on the ICBM problem for more than eight years. Just after World War II, the Air Force had awarded the Convair Corporation a $1.4 million contract to develop a long-range ballistic missile called the MX-774. Like many of the postwar missile projects, the MX-774 lost most of its government funding after only one year. Instead of simply abandoning the effort, however, Convair decided to pursue the research on its own.[54]

When the company started working on the project in 1946, the V-2 was still considered to represent the state of the missilemaker's art. The German missile had a range of approximately 200 miles. Nonetheless, the Air Force wanted Convair to create a missile capable of reaching targets more than 5,000 miles away. "This," observes Jacob Neufeld,

---

[53] Roy Neal, Ace in the Hole (Garden City, NY: Doubleday and Company, 1962), 64-65.

[54] Much of the information in this section was drawn from Neufeld, Development of Ballistic Missiles, 44-50; 69-78. For a concise history of the MX-774 project, see Beard, Developing the ICBM, 50-67. For a detailed overview of the Atlas project, see John Chapman, Atlas: The Story of a Missile (New York: Harper & Brothers, 1960).

"represented a staggering requirement."[55]

The company could have attempted to meet the Air Force requirement by building an enormous version of the V-2. Instead, Convair engineers sought a more sophisticated solution. Realizing that the range of a missile could be greatly increased by reducing its weight, they decided to equip the MX-774 with an ultra-light airframe.

The V-2 consisted of a wingless, but otherwise conventional aircraft-style fuselage with separate fuel and oxidizer tanks mounted inside.[56] In the MX-774, Convair eliminated this heavy, double-walled arrangement by making the tanks themselves serve as the airframe. The company's engineers accomplished this by designing the tanks with thin, sheet-metal skins that were inflated like footballs to give the missile its structural rigidity.

As the MX-774 project moved forward, Convair made significant improvements in rocket propulsion and guidance systems, and solved many of the problems associated with the vehicle's reentry into the atmosphere. The Air Force quietly acknowledged these achievements in 1951 by hiring the company to develop a more advanced missile. This one would be called the Atlas.

The new missile would essentially be a highly evolved version of the MX-774. Its featherweight airframe would be assembled from rings of paper-thin stainless steel, stacked together like stovepipes and welded at the seams to form flimsy cylinders. These cylinders would be pressurized with nitrogen gas to make the missile stand up straight. The final

---

[55] Neufeld, Development of Ballistic Missiles, 44.

[56] The V-2 had four small fins mounted near its aft end. These fins helped to stabilize the missile in flight, but provided no aerodynamic lift, and were therefore not considered to be wings.

configuration was eventually likened to a "flying beer can."[57]

By 1954, the Atlas Project was the nation's most advanced ballistic missile program. Still, not everyone was certain that the "beer can" would ever get off the ground. The missile was years away from production. No prototype had been flight tested, and some skeptics feared that when the missile's powerful rocket engines were fired for the first time, the thin-skinned airframe would simply buckle in on itself, leaving America's hopes for an ICBM lying on the launch pad like a gigantic ball of tin foil.

The officers of the Western Development Division were well aware of these concerns. They also believed, however, that the nation's security depended on their ability to produce a viable long-range ballistic missile as soon as possible, and the Atlas gave them a much-needed head start. So when General Schriever and his staff went to work in Inglewood, their first priority was to accelerate the pace of the Atlas program. At the same time, they began to search for a backup system.

AN ALTERNATE ICBM: TITAN

During the fall of 1954, the Western Development Division asked the Lockheed Aircraft Corporation and the Glenn L. Martin Company to undertake engineering studies for a second ICBM. By Christmas both companies had recommended building a new missile

[57] Anderson Ashburn, "How Convair Assembles the Atlas," American Machinist 104 (11 January 1960): 73.

with a more advanced propulsion system than that of the Atlas.[58]

The Atlas had three rocket engines, mounted side by side on the missile's aft end, and fed from a single set of fuel and oxidizer tanks.[59] During a launch, all three engines were designed to ignite simultaneously on the ground, providing the tremendous burst of energy required to lift the Atlas off the launch pad and boost it into the upper atmosphere. Once liftoff had been achieved, the two outer "booster" engines would be jettisoned. The remaining "sustainer" engine would continue to burn until the missile reached its full altitude.

By starting all the missile's engines on the ground, Atlas engineers avoided the potentially difficult problem of trying to ignite an internal combustion engine in a vacuum. But they paid for their peace of mind with a significant reduction in the missile's range and efficiency, because the Atlas configuration required the sustainer engine to waste much of its energy propelling the considerable "dead weight" of the missile's enormous, half-empty fuel and oxidizer tanks.

The new missile proposed by Lockheed and Martin would utilize a "two-stage" design. The missile would be equipped with separate booster and sustainer engines, each supplied by its own set of fuel and oxidizer tanks. The engines would provide their thrust in two distinct firing stages. As soon as each firing stage was completed, the engine and its

---

[58] The origins of the Titan program are discussed in Alfred Rockefeller, Jr., "History of Titan, 1954-1959," 1960, pages 1-9. TMs [photocopy]. BMO, Box L-1. Rockefeller was the unit historian for the Western Development Division.

[59] As its name implies, the oxidizer provided the oxygen that enabled the engines to burn fuel in the airless environment of space. The Atlas propulsion system used liquid oxygen (LOX) as an oxidizer and alcohol for fuel.

associated tankage would be discarded. Because the missile would shed a substantial proportion of its weight in flight, it could carry more weight at take-off. Consequently, the new missile could utilize a heavier, more conventional -- and more reliable -- airframe.

With this information in hand, General Schriever sent a formal proposal to the Air Research and Development Command in January 1955, requesting permission to initiate development of a two-stage ICBM. At the end of April, the Secretary of the Air Force authorized the Western Development Division to proceed with the project.

By this time, the agency's staff had already evaluated the credentials of nearly eighty potential contractors for the second ICBM, identifying eight that would be qualified to build the new missile.[60] After studying the list, General Schriever concluded that no individual manufacturer offered any "outstanding advantage" over the others, and decided to award the contract on the basis of a competition.[61] "It is possible," he wrote, "that such an approach might provide a substantially superior [design] . . . and . . . provide a chance for great advancement even with a late start."[62] On 6 May 1955, the Air Force invited all of the pre-qualified contractors to submit proposals for the project. Only Lockheed, Douglas Aircraft, and the Glenn L. Martin Company responded.

---

[60] According to a 1955 memorandum written by WDD Deputy Commander Colonel Charles H. Terhune, Jr., the short list included Convair, North American Aviation, Boeing, Douglas, Lockheed, Bell, Hughes, and the Glenn L. Martin Company. See Colonel Charles H. Terhune, Jr. to Lt. General T. S. Power, Commander ARDC, 31 January 1955. HRA K243.012-57, September 1955-February 1961, ICBM 2-14-2, Contractor Relations, Vol. 7.

[61] Brigadier General B. A. Schriever, Memorandum for the Record, August 1955, HRA K243.012-57, September 1955-February 1961, ICBM 2-14-2, Contractor Relations, Vol. 7.

[62] Quoted in Rockefeller, "History of Titan," 2.

In mid-August the WDD's Contractor Evaluation Board convened in Inglewood to study the proposals. Four weeks later, the Board summarized its findings in an eight-page report. After analyzing each contractor's plans for management support, design, testing, and quality control, the report recommended "the immediate selection of the Glenn L. Martin Company [for the] development contract."[63] The recommendation was approved by the Air Force Chief of Staff in early October, and by the end of that month, the Glenn L. Martin Company had been hired to build the nation's second ICBM.

THE SYSTEMS CONCEPT AND THE QUEST FOR RELIABILITY

Martin would not be working on the project alone. The Titan missile would be composed of a number of distinct and highly complex sub-systems, including the airframe, the propulsion and guidance systems, and the warhead. Each of these subsystems presented scientists and engineers with a daunting array of new technical challenges. Recognizing that no individual manufacturer was likely to possess either the "across-the-board competence in the physical sciences" or the "caliber of scientific personnel" required to meet these challenges, the Western Development Division decided to seek outside help.[64]

They turned to the Ramo-Wooldridge (R-W) Corporation, an independent, technological brain trust that had been established in 1953 by two former Hughes Aircraft engineers, Simon Ramo and Dean Wooldridge. Ramo-Wooldridge had already served as a

---

[63] "Report of the Contractor Evaluation Board, Alternate WS 107A Airframe," 14 September 1955, HRA K243.012-57, September 1955-February 1961, ICBM 2-14-2, Contractor Relations, Vol. 7.

[64] Schwiebert, History of USAF Ballistic Missiles, 84.

consultant on the Atlas project. Now the company was asked to provide the technical direction and "systems engineering" for the Titan.[65] In systems engineering, explained one Ramo-Wooldridge scientist,

> primary emphasis [is placed] on the relationships of the various portions of a [weapon] system to one another and [on] overall system performance. A missile is initially planned in broad outline, essentially in block diagram form, and the interactions of the different parts with one another are studied in detail before any hardware designs are committed.[66]

This was the process adopted for the Titan. After Ramo-Wooldridge engineers identified all of the missile's essential subsystems and defined the relationships among them, they prepared a set of basic design parameters for each one. With these specifications in hand, the Western Development Division initiated a national search for suppliers, assigning responsibility for the detailed design of each subsystem to a manufacturer with demonstrated expertise in that particular field. This approach enabled the Western Development Division to significantly shorten the overall development timeline for the Titan, because research and development for all of the missile's most important subsystems occurred simultaneously.

By the end of 1955 the Titan team was in place. The Aerojet-General Corporation of Sacramento won the contract for the missile's rocket engines. Bell Laboratories in Whippany, New Jersey and Remington Rand Univac in St. Paul, Minnesota shared responsibility for the guidance system. The AVCO Manufacturing Company of Lawrence,

---

[65] For a concise history of the Ramo-Wooldridge Corporation's origins and involvement in the ICBM program, see Schwiebert, History of USAF Ballistic Missiles, 80-85; and Neufeld, Development of Ballistic Missiles, 99.

[66] For a definition of the systems concept and brief explanations of how a missile's most important subsystems operate, see Duane Roller, et al, "Notes on the Technical Aspects of Ballistic Missiles," Air University Quarterly Review" 9, (Summer 1957): 34-68.

Massachusetts took charge of designing the missile's nosecone, and the Sandia Corporation of Albuquerque, New Mexico, was hired to develop the Titan's thermonuclear warhead. Smaller components would come from dozens of subcontractors located all across the country. As the prime contractor for the project, the Glenn L. Martin Company was responsible for building the Titan's biggest piece -- the airframe -- and for making sure that the missile functioned flawlessly when all the other pieces were added to it. Simon Ramo illustrated the difficulty of this assignment:

> Suppose we ask for a modest 50 percent chance that the complete system will [operate] without a malfunction of some major subsystem. For simplicity, let's say there are five or six of these main subsystem elements, with an equal chance that one of them will function improperly during flight. Then, to have a 50 percent chance for a completely successful flight, each of these subsystems must be counted on for roughly a 90 percent chance of operating perfectly. But each of these subsystems itself consists of hundreds of critical components, which must then have an average reliability during flight in the 99.9 percent region, with a failure of only one in a thousand.[67]

In an effort to improve the Titan's chances for success, the Western Development Division asked Martin to implement what was later described as "one of the most comprehensive test programs ever formulated for a machine."[68] The program would begin at the most basic level, with rigorous quality control and testing for thousands of individual missile components. As the components were put together to form assemblies, subsystems,

---

[67] Ramo included these comments in an address to the American Rocket Society. See Simon Ramo, "The ICBM Program -- Its Relation to Past and Future Developments," June 1957, pages 4-5. TMs. BMO, Box F-4, File J-4-4-10. The text of Ramo's speech appeared under a different title in Astronautics a few months later. See Simon Ramo, "ICBM: Giant Step Into Space," Astronautics 2 (August 1957): 37-38.

[68] "Testing a Titan," Astronautics 4 (August 1959): 26. For a thorough description of the Air Force ICBM test philosophy, see Edwin A. Swanke and Richard K. Jacobson, "The Ballistic Missile Test Program," Air University Quarterly Review 9 (Summer 1957): 108-120.

and finally whole missiles, they would be repeatedly and exhaustively tested at every turn. The results of these tests would be carefully recorded and analyzed to make design improvements. The program would eventually culminate with flight testing of entire missiles, but as Ramo pointed out, "flights of guided missiles are measured in minutes . . . [so] hundreds of flights may be needed to accumulate a single hour of experience."[69] Each of those flights would terminate with the destruction of an extraordinarily expensive test missile. Consequently, as much of the Titan test program as possible would be carried out on the ground.

Before this ambitious test program could be put into place, however, an enormous hurdle still had to be overcome. As General Schriever recalled a few years later, there were "essentially no industrial facilities and certainly no test facilities to support the huge Titan research and development effort."[70]

THE FIRST FULLY-INTEGRATED ICBM FACILITY IN THE WORLD

When Martin originally decided to bid on the Titan project, company officials assumed that if they won the contract, they would be able to build the new ICBM in their Baltimore airplane plant. But as the details of the project started to unfold, it quickly became apparent that the existing factory would have to be extensively altered to accommodate the Titan. Furthermore, the use of the Baltimore facility would violate a new

---

[69] Ramo, "The ICBM Program," 5.

[70] Bernard Schriever, "Titan," [ca. 1960], page 1. TMs [photocopy]. HRA, 168.7171-128.

Defense Department directive stating explicitly that "the design, development and construction of the missile is to be accomplished in the central part of the United States, well away from either seacoast."[71]

Consequently, Martin began prospecting for a place where it could build an entirely new plant. During the spring and summer of 1955, the company's site selection committee visited 94 cities in 33 states in search of a suitable location. When Martin received the contract in October, the search had narrowed to Salt Lake City or Denver. After intensive lobbying by the Denver Chamber of Commerce, Martin agreed to purchase 4,300 acres southwest of Denver from rancher C. K. Verdos, and to lease an adjacent 2,200-acre tract with an option to buy. Situated in the foothills of the Rocky Mountains behind a long, high ridge known as the "Hogback," the property was near existing roads, rail lines, and water supplies.[72]

On this site, the Glenn L. Martin Company began to build what General Schriever called "the first completely integrated factory/hot test facility available to the ballistic missile program."[73] The company later explained the term:

Reference to Martin-Denver as an integrated missile facility stems from the

---

[71] Memo from Commander Air Research and Development Command, Baltimore to Commander Western Development Division, Inglewood, May 1955. TMs. HRA, K243.012-57, September 1955-February 1961, ICBM 2-14-2, Contractor Relations, Volume 7. According to Jacob Neufeld, this so-called "dispersal policy," was "intended to lessen the vulnerability of [missile-related] industries to enemy attack." See Development of Ballistic Missiles, 129.

[72] The selection process is chronicled in detail in the Chamber of Commerce newsletter. See "Now It Can Be Told," Denver (8 December 1955).

[73] Schriever, "Titan," page 11.

> fact that here . . . an engineer's line drawing can be transformed into a complete weapon system, including design, fabrication, and captive testing. This facility is a complex of administrative, engineering, and manufacturing buildings, laboratories, test fixtures, and four giant captive-firing stands. According to U.S. Air Force authorities, Martin-Denver is the only facility of its type in the western world, and probably the entire world.[74]

THE FIRST TITAN

The first structure erected at the Denver complex was the administration/engineering building, which was completed on the last day of November 1956, just ten months after the groundbreaking ceremony at the site. By the time Martin moved its employees into the new edifice, the Titan's essential specifications had been firmly established.[75]

The initial design showed a missile that stood 98 feet high and weighed 220,000 pounds when fully loaded with propellants. Its two propulsion stages were stacked one on top of the other, and supported a re-entry vehicle [nosecone] carrying a four-megaton thermonuclear warhead. Each stage consisted of two cylindrical tanks (one for fuel, the other for oxidizer) linked together by simple sheet-metal fairings. The fairings housed engine support structures and a complex array of hydraulic, pneumatic, and electrical equipment.

---

[74] "Facts About Martin-Denver," Martin Press Release dated 17 October 1958, included in collection of the Western History Department, Denver Public Library. Filed under Business and Industry: Colorado: Aircraft: Glenn L. Martin Company.

[75] For a concise summary of the Titan I's specifications, see "Titan Fact Sheet," n.d. TMs [photocopy]. Collection of Western History Department, Denver Public Library. Filed under U.S. Armed Force: Missiles: Titan. Also see "Titan I (SM-68)," n.d. TMs. Available from BMO History Office, Norton AFB, CA. An excellent description of the airframe may be found in Russell Hawkes, "Martin Proposes Improved Titan System," Aviation Week 72 (11 January 1960): 56-59.

The Titan's airframe was designed to utilize conventional aircraft construction techniques. The missile's outer skin was made of aluminum-alloy panels, that were extruded with integral longitudinal stiffeners and chemically milled in non-structural areas to reduce the missile's overall weight. The panels were attached to a framework of ring-like internal supports. This structural system ensured that the Titan, unlike the Atlas, would be able to hold itself up without the aid of internal pressurization.

The missile's first stage, measuring ten feet in diameter and 57 feet in length, was to be powered by a dual-nozzle Aerojet-General rocket engine capable of developing 300,000 pounds of thrust -- roughly equivalent to the "horsepower of 15,300 average-size American automobiles."[76] After this "booster" engine burned out, a set of explosive connecting bolts detonated automatically, releasing the first stage. The eight-foot diameter second-stage and its deadly payload would then continue the journey, achieving speeds in excess of 15,000 miles per hour, under the impetus of a single-nozzle Aerojet "sustainer" engine capable of producing 80,000 pounds of thrust. The booster and sustainer engines were designed to burn a mixture of liquid oxygen (LOX) and RP-1 jet fuel, which was essentially kerosene. The Titan's intended range was at least 6,000 nautical miles. To keep the missile on course, the second stage contained a gyroscopic, radio-inertial guidance system that established the proper trajectory by responding to commands from ground tracking stations.

Early on the morning of 4 February 1957, 63 production line employees reported to work at the Denver plant's newly completed factory building. Within a few days, they

[76] "Titan Fact Sheet."

would begin to convert the Titan concept into a reality.[77] As these workers punched in for the first time, Martin was already preparing to meet the missiles when they rolled off the assembly line.

TEST FACILITIES

When a new Titan emerged from the factory, it went directly to Martin's vertical test facility (VTF), a 13-story structure containing enclosed test cells where the missile's stages were assembled for the first time. Inside these cells, the missile was fully pressurized and subjected to many of the stresses it would encounter in flight: "the outside is heated to 600° F., the inside simultaneously cooled to minus 300° F. [and] hydraulic forces of 300,000 lb. are applied to the engine compartment."[78] At the same time, test engineers ran the missile through a simulated countdown to check out every system and subsystem. The Titans that remained intact after this ordeal were purchased by the Air Force, but their testing was not yet complete. Still in the offing was a trip to Martin's hillside test stands where "the mammoth rockets will be chained down while their huge motors are static tested."[79] Once a missile had proved itself on the test stands, it was ready to fly.

Martin initiated work on the captive test stands during the fall of 1956, enlisting some expert assistants to help with the project. As part of the accelerated development process

---

[77] "Machinery to Turn at Martin Plant Monday," DP, 1 February 1957.

[78] "How a Titan Gets Ready to Fly," Business Week (5 December 1955): 99.

[79] Henry Still, "Hill Near Denver Being Altered for Testing of H-Bomb Missiles," RMN, 18 September 1956.

known as "concurrency," the Western Development Division urged contractors to eliminate duplication of effort whenever possible by building on prior research. In keeping with this policy, Martin hired the propulsion contractor Aerojet-General, which had already built Titan engine test stands at its Sacramento headquarters, to prepare the plans for the Denver installation. Because the new test stands would be used not only to test missiles but also to check out prototype ground support equipment and to train launch crews, Aerojet engineers had to incorporate virtually every feature of the operational launch pads into the Martin designs. The actual construction of the facilities was supervised by the George A. Fuller Company, general contractor for the Martin plant.[80] The project was funded by the United States Air Force.

Work on the test stands proceeded slowly over the next few months -- hindered first by a dispute with the electricians' union, and then by a period of unusually heavy rain that washed out access roads, undermined newly poured foundations, and eroded the surrounding hillsides, burying the test sites beneath tons of mud and rock. Despite these setbacks, the major components were in place by the spring of 1957, and by mid-June, Aviation Week was able to report that the "firing facilities are nearing completion."[81] The captive test facilities at Martin-Denver were tucked into the foothills behind the main plant, and connected to it by a network of narrow, twisting, asphalt roads that climbed more than a thousand feet in less

---

[80] "Plant Could Be Completed At Early Date," Martin-Denver Missile 1 (8 June 1956): 1.

[81] George L. Christian, "Martin Denver Integrates Titan Needs," Aviation Week 66 (17 June 1957): 73. The construction problems are chronicled in George McWilliams, "Union Dispute Halts Work on Missile Plant," DP 27 November 1956; and "History: AFPRO Martin-Denver, 1 March-30 June 1957," page 11. HRA K208-29.

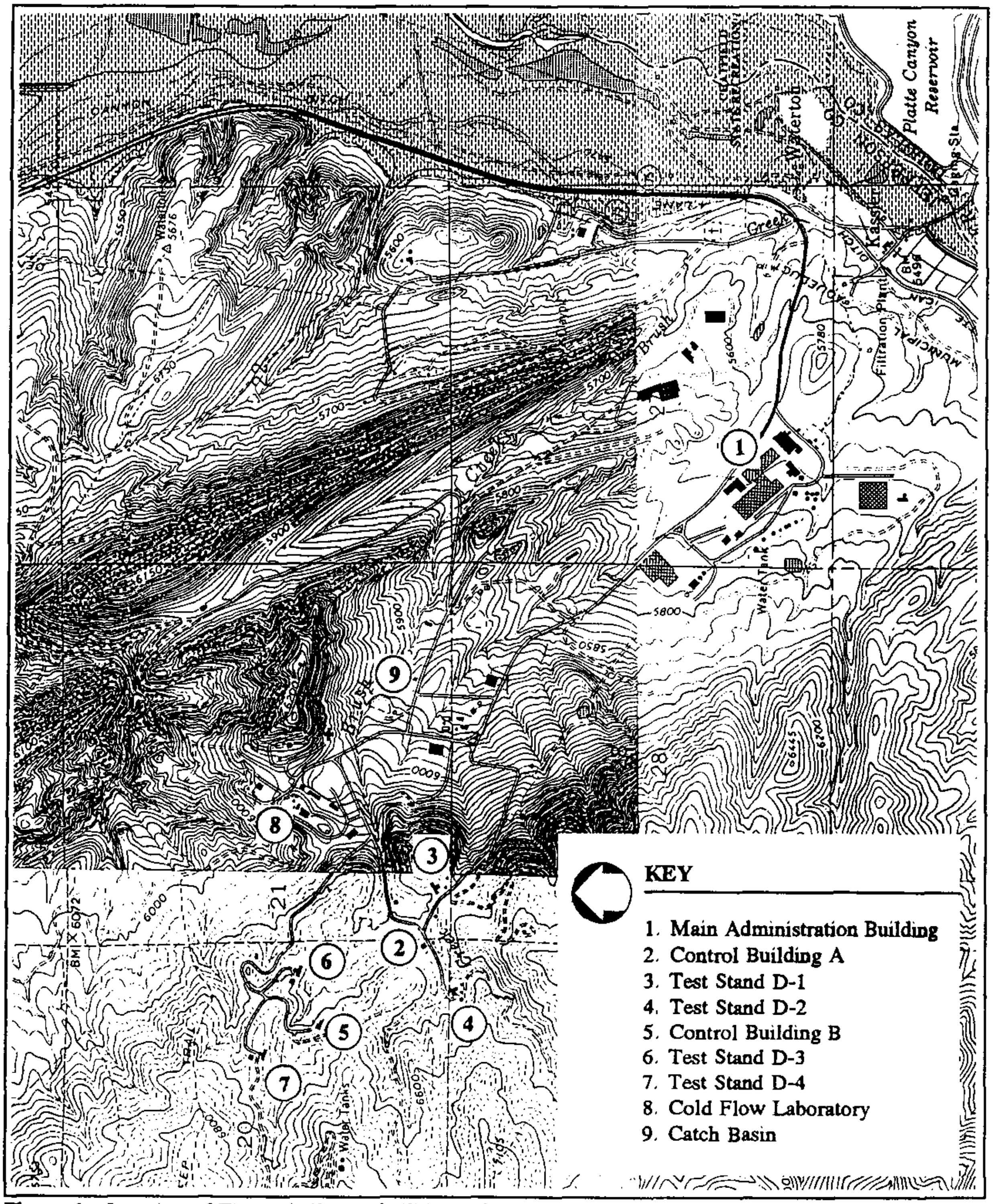

Figure 1. Location of Titan missile test facilities at the Glenn L. Martin Company plant near Denver. *Source: USGS quads for Kassler, Platte Canyon, Indian Hills, Littleton, CO.*

than two miles. [Figure 1] The installation comprised two distinct complexes. Each complex had its own central control building, linked by tunnels to a pair of widely separated test stands. Sheltered in natural box canyons, the individual stands were "arranged so that any one may be fired without danger to technicians who might be working at any of the others."[82]

Flame Deflectors

Whenever a large rocket engine was fired, its nozzles spewed forth a devastating plume of hot gas and flame 75 to 100 feet long. Safe disposal of this exhaust presented test stand designers with one of their most difficult challenges. For many years, propulsion engineers had attempted to solve the problem by building rocket test stands high on the sides of cliffs. By hanging engines over the edge, they could provide 100 feet or more of free drop for the hot exhaust gases. But even at this distance, the flame from a rocket engine would often "cut out ground and concrete at the rate of an inch or more per run." Engineers eventually solved the problem by equipping test stands with "flame deflectors" designed to turn the flame from a rocket engine 90 degrees as soon as it left the nozzle. The flame

---

[82] Descriptions of the test facilities are based on several sources of information, including field inspections of the facilities by John Lauber during June 1993. The best published description of the test stands appeared in Russell Hawkes, "Hardened Titan Bases Require Specialized Support," Aviation Week 72 (18 January 1960): 77-78. Additional sources include original project blueprints located in the Plant Engineering Department at Martin-Marietta Astronautics Group, Denver, CO. The company's Photographics Department maintains a large collection of black and white and color photographs depicting construction, equipment, and test activities at the stands during the period 1955-1960. Paul Hixenbaugh and Don Picker provided a wealth of information about operations at the test stands. Hixenbaugh, a former Martin Engineer, was interviewed by the author on 3 June 1993 in Denver. Picker was responsible for maintenance at the test stands during the late 1950s and early 1960s. The author interviewed him by telephone on 30 August, 17 September, and 28 September 1993.

deflector made it possible to build test stands "much smaller, simpler, and much less expensively than before."[83]

Each of the test stands at Martin-Denver was designed around a pair of 25 foot wide, 38 foot high flame deflectors standing side by side on the canyon floor. Resembling truncated ski jumps, the deflectors had C-shaped, structural steel side frames, tied together at the top by a pair of transverse box girders. The C-frames supported broad, backward-sloping panels that curled sharply upward at their lower edges. The panels were of hollow construction, with cast-concrete inner walls and steel-plate outer walls. The face of each deflector panel was cooled with water from a huge hilltop storage tank. A pipe manifold attached to the back of each structure was designed to deliver the coolant at the rate of 30,000 gallons per minute.

The deflectors were more than just monumental exhaust pipes, however. They also had to withstand the tremendous -- and opposing -- forces exerted upon them by gravity and thrust. A propellant-filled Titan placed a burden of 220,000 pounds on its test stand. But when the firing button was pressed in the control room, all this weight abruptly changed direction, as the missile's powerful rocket engines strained upward with as much as 300,000 pounds of thrust. To counteract these loads, the C-frames were anchored to massive concrete footings that extended to the bedrock below. The tops of the frames cantilevered outward over the deflector panels, forming supports for the heavy steel "thrust rings" to

---

[83] Both quotations in this paragraph are taken from Brigadier General Ben I. Funk, "Impact of the Ballistic Missile on Industry, Part III: From a Rocket Engine Producer's Viewpoint," Air University Quarterly Review 9 (Summer 1957): 103. This section of the article was prepared by the Rocketdyne Division of North American Aviation.

which the Titans were attached. To provide additional lateral support, each pair of deflectors was laced together at the center with a webwork of structural steel struts.

Counterfort

Stretched across the canyon behind each pair of flame deflectors was a two-foot thick counterfort wall built of reinforced concrete. Spanning the gap between the counterfort and the C-frames was a bridge-like steel work platform with an I-beam substructure, open deck grating, and removable pipe rails along the front and both sides. A massive steel-plate blast barrier was mounted near the front of the bridge to keep each stage from being damaged by the flames of the other.

The counterfort also formed the outer wall for two large, bunker-like, reinforced-concrete rooms that were built into the hillside. At one end of the wall was a 40 by 44 foot transfer room -- essentially an enormous junction box, filled with racks of electrical equipment. The transfer room opened into a partially exposed, reinforced-concrete tunnel that served as a conduit for thick bundles of instrumentation and power cables connecting the test stand to the control building. Rectangular in section and measuring approximately 4 by 7 feet on the inside, each tunnel was large enough for a person to walk in. The cables were laid out on open trays inside to provide ready access for repairs.

At the opposite end of the counterfort was a 34 by 45 foot room containing electrical and hydraulic equipment. Extending back from the face of the counterfort was a thick, reinforced-concrete slab, that served as a roof for the subterranean rooms and provided a flat, spacious work area for technicians and vehicles at the test site. A covered ramp along each edge of the slab provided access to the rooms below.

Positioned off to one side of the work area were two prefabricated, galvanized steel support buildings. Each of these one-story structures was rectangular in plan, measuring approximately 38 by 45 feet, with a low-pitched, front-gabled roof, and a sliding door at one end. The support buildings provided weather protection, shop space, and storage facilities for the test stand crews.

Erectors

The most prominent structures at each test stand were the two tilting, red-and-white-striped erector towers that were used to position the Titan's stages for firing. Fabricated by the Kaiser Steel Corporation to Martin specifications, the erectors were rigid, U-shaped frameworks of square-section steel tubing, designed to surround the missile on three sides. Each tower was intended to serve as a combination crane/scaffold/service station for one section of the missile, with an array of equipment that included a cable hoist; a battery of hydraulically operated, flip-down work platforms; a water-deluge fire-protection system; and a tangle of hoses and cables that supplied the missile with propellants and electrical power. The taller of the two erectors stood 104 feet high, weighed 116 tons, and was big enough to accommodate a fully assembled Titan. The second erector was considerably shorter, since it was designed to handle the second stage only.

A low, cradle-like trailer called a "transtainer" transported each Titan stage up the hill from the vertical test facility to the captive test area. When the trainstainer arrived at its assigned test stand, technicians drove it up a ramp into the lowered erector tower, and attached cables to the sides and top of the missile stage. Workers then tightened the cables, retracted the wheels on the transtainer, and pulled the trailer out from under the missile. Once the transtainer was out of the way, the erector tipped the stage up into the vertical test position.

Each erector was designed to pivot on pillow blocks attached to the top of the C-frames. An electric winch located beneath the concrete work platform raised and lowered each tower with the help of an elaborate system of cables and pulleys. The winch cables passed first over a set of pulleys attached to a steel frame located between the counterfort and the flame deflectors. Then they wrapped around a movable drum mounted below. As the winch cables tightened, the drum moved slowly upward in its frame. Stout steel arms attached to its axle pushed the erector up and locked it into the vertical position. As the tower passed the balance point on the way up, hydraulic cylinders in the front legs extended to break the fall. When the erectors reached the upright position, the missile stage was lowered onto the thrust rings, bolted down, and readied for firing.

Propellant Handling Equipment

The cryogenic liquids in Titan's propulsion system posed special problems for test stand designers. These fluids included liquid nitrogen, essentially the lifeblood of the pneumatic systems, and liquid oxygen (LOX), used to support combustion of the missile's fuel. Because of its extreme volatility, LOX particularly influenced the design and maintenance of the test stand environment. As Air Force engineer Paul Troxler has noted, even the most mundane feature, such as paving, received careful scrutiny to ensure compatibility:

> Where [LOX] spillages are likely, portland cement concrete paving must be used, since the interaction of the liquid oxygen and bituminous material produces explosive mixtures. For the same reason, joints in concrete pavement must be filled with a material compatible with LOX. Systems containing LOX must be cleaned to surgical standards, for two reasons. One is to prevent contaminants from getting into the missile system, and the other is to eliminate organic contaminants, such as oil and grease, which combine violently with LOX. Electrical installations in areas where liquid oxygen is being handled must be explosion-proof.[84]

The super-cold LOX boiled at minus 297° Fahrenheit. To prevent it from literally vanishing into thin air, the liquid was stored in insulated, stainless-steel, 28,000-gallon tanks until shortly before ignition. By this means, boil-off loss was kept to less than 140 gallons per day. The LOX tanks stood behind reinforced-concrete blast walls, about 150 feet to the rear of the flame deflectors. Two 500 gallon-per-minute pumps at each location transferred the LOX to the missile.

The main LOX fill lines were routed through the erectors. But because the LOX boiled off rapidly in the Titans' uninsulated oxidizer tanks, the missiles required repeated "topping off" even after the erectors were lowered for firing. To accomplish this task, supplementary LOX fill lines for the two stages were suspended from booms on tripodal, tubular steel "umbilical towers" rising from the canyon floor next to each pair of flame

---

[84] Paul D. Troxler, "Space Missile Facilities," The Military Engineer 53 (March-April 1961): 105-106.

deflectors. The umbilical towers also supplied the missile with nitrogen, hydraulic fluid, pressurized helium, electrical power, and a steady supply of cool air to keep delicate electronic gear from overheating.

The other component of the Titan's propellant system was kerosene. Compared to LOX, it was blissfully easy to handle:

> RP-1 narrow-cut kerosene fuel is stored in two 20,000-gal. tanks near the blockhouse. [A] centrifugal transfer pump can move fuel at 600 gpm. As fuel evaporation is too slow to require continuous precision topping of missile tanks, all fuel fill lines are routed via the erectors. [A] centrifugal pump at the pad can be used to return fuel to the storage tanks if a launching is scrubbed.[85]

In case of emergency, both LOX and kerosene could be dumped into separate holding ponds on either side of the test stand. The cooling water from the flame deflectors flowed into a large catch basin located further down the hill. A funnel-shaped, ferrocement apron lined the floor and sides of the canyon surrounding the test stand to collect the water. Channels formed into the floor of the apron then directed the runoff into an open flume that emptied into the basin below.

Control Buildings

The captive firing facilities played a crucial role in the research and development process at Martin-Denver. The tests were elaborate and noisy experiments whose sole purpose was to provide engineers with the information they needed to make the missiles

---

[85] Russell Hawkes, "Hardened Titan Bases Require Specialized Support," Aviation Week 72 (18 January 1960): 77-78.

more reliable. But as one Martin engineer pointed out, "the nature of the missile and its behavior defy . . . direct human observation."[86]

Consequently, most of the observation at Martin-Denver was done by proxy. The Titans on the test stands were wired up like patients in an intensive care ward, with sensors to monitor every vital sign. The information they collected was fed into banks of recording instruments located inside the fortress-like, two-story control buildings located more than 200 yards away from the test stands.

Each of the control buildings was rectangular in plan, measuring approximately 59 by 99 feet, with parapet walls and a flat roof. Built entirely of reinforced concrete, each structure had foot-thick walls capable of withstanding the blast from nearly half a million pounds of TNT. Centered in the front of each building was a three-sided entrance bay containing a double pair of heavy steel blast doors that looked as though they belonged on a bank vault.

Each building had its own heating, ventilating, and cooling systems, as well as a water supply and emergency generating equipment. The first floor of each control building contained small rooms for mechanical equipment, a shop, and a toilet. In the remaining space stood row upon row of locker-like steel cabinets filled with electrical apparatus. The second floor contained launch control and data recording equipment for two test stands.

Operations at each test stand were directed from a piano-sized console called the

---

[86] Ben I. Funk, "Impact of the Ballistic Missile on Industry," Air University Quarterly Review 9 (Summer 1957): 100.

Master Operational Controller. Each console contained a computer programmed to monitor, control, and troubleshoot virtually every aspect of a static test. From this central location, test engineers controlled erectors and propellant loading systems, directed the countdown, checked out each of the missile's subsystems and, if so required, stopped the firing altogether.

There were just six small, porthole-like windows in each control building -- three on each side of the entrance bay. Fitted with two-inch thick laminated glass, these blastproof windows were reserved for use by visiting dignitaries and other casual observers. The engineers and technicians who actually ran the tests watched the proceedings on closed-circuit television, while an array of remote-controlled still and motion-picture cameras mounted on hillside platforms created a permanent visual record of the events taking place below.

Activation

On 3 December 1957, the Martin Company announced that it would conduct its first engine test firing within the next two weeks. "We're about ready to torch one off," warned plant manager Howard W. Merrill. "So if you hear some new strange noises around here and see some strange lights in the sky, you'll know what it is. The exact time schedule will depend on the preparations at the test facilities."[87]

Despite Merrill's prediction, the "strange noises" did not begin for nearly three more months. Meanwhile, Martin complied with a longstanding Defense Department policy by

[87] "First Titan Rocket Engine to be Fired Near Denver," RMN, 4 December 1957.

transferring ownership of the 464-acre test site to the Air Force.[88] Finally, at 3:30 p.m. on 5 March 1958, test engineer Elwood Chick pressed the firing button on the console in Control Building A, and the Aerojet booster engine mounted on stand D-1 came to life:

> There was an explosion as the engine fired. You could feel the tremor in the blockhouse . . . . White smoke rose steadily from the confines of the test stand . . . billowed over the area, and hid the stand from view.[89]

The first test firing lasted for only a few seconds. But in the view of at least one reporter, the event marked "an important milestone in Titan development and U.S. counter-aggressive ability."[90]

THE TEST STANDS AS A DEVELOPMENT TOOL

It took nearly eighteen more months for Martin's captive test facilities to become fully operational. Test stand D-2 was first used in July 1958. Test firings began on stand D-3 in February 1959, and stand D-4 was activated in August of the same year.[91] As part of the research and development process, the Titans were produced in a series of progressively more complex batches or "lots," beginning with several groups of non-flight "research and

---

[88] "Martin Deeds 464 Acres to Government," DP, 21 February 1958. Aviation Week writer David Anderton explained the origins of the policy: "The reasoning was that if any contractor were to build and operate a [test stand] . . . the mere possession of [it] would give him the inside track, if not the only car in the race, when it came to getting contracts for high-thrust rocket engines. So in 1946, the powerplant lab at Wright-Patterson [Air Force Base] decided the only solution was to have the Air Force build and operate the stands for use by all civilian contractors." See David A. Anderton, "AF Tests Rocket Engines in Giant Stands," Aviation Week 59 (31 August 1953): 24.

[89] Wm. B. Higdon, "Precise Preparations Lead to Test Firing," Martin Denver Missile 3 (14 March 1958): 2.

[90] "First Titan ICBM Rocket Engine Test Fired Southwest of Denver," RMN, 6 March 1958.

[91] Schriever, "Titan," 11.

development" missiles. As each lot was tested, engineers identified problems, devised solutions, and incorporated the changes into next lot. This process was followed until the final operational weapon system was achieved. As the missile evolved, the test stands were constantly altered to accommodate design changes. Consequently, "the test stand completions were programmed so as to become available as the various missile lots were ready for static test operations."[92]

The Test Plan

Engineers initiated the captive test program for each lot by developing a detailed written test plan. Each plan included a description of every component or subsystem to be tested, an outline of test objectives, a schedule, a list of necessary equipment and facilities, and a summary of the procedures to be followed.[93]

As the test plan was implemented for each missile in the lot, the results of all the tests were recorded in a series of logbooks. The logbooks followed each missile through the entire production and testing process. Thus, when the full test sequence had been completed, engineers had a complete history for each missile, chronicling the performance of every component in stringent detail. These individual histories were eventually analyzed and incorporated into a Lot Test Report, which pointed out problem areas and made

---

[92] "Report on Denver Missile Test Activities: Titan I Program" (Denver: Space Technologies Laboratories, 1963), 1. This document is included in the collection of the TRW Technical Library, Norton AFB, CA. Document no. 24972cc 6460-1090 cart 001 1 1963.

[93] "Test Requirements for Weapon System 107-A-2 at the Denver Test Facility" (Los Angeles: Ramo-Wooldridge Corporation, 1957), 3.3. BMO, from TRW Archives, Norton AFB, CA.

recommendations for modifying the next lot.

Propulsion System Tests

The "hot test" program for each missile started with a series of "battleship firings," designed to identify potential incompatibilities between the Aerojet-General rocket engines and the Martin-designed propellant feed system. These tests took their name from the fact that the engines were not attached to the missile's lightweight aluminum propellant tanks, but were connected instead to a set of heavily armored stainless steel tanks that were permanently mounted on test stand D-1. These "battleship" tanks allowed test engineers to run propellant and propulsion tests without having to worry about rupturing tanks or fuel lines.[94]

The Martin Company tested the components of the Titans' propellant feed system at a separate "cold flow laboratory," designed by Aerojet-General. Located on the Air Force property between the test stands and the main plant, the cold flow complex consisted of a blastproof, one-story, reinforced-concrete control building, linked by tunnel to a series of enclosed test cells. The one-story, reinforced-concrete test cell building contained three austere, garage-like stalls where individual components such as valves, seals, or pumps were exposed to the effects of cryogenic liquids. Rising from one end of the test cell building was a twelve-story, steel-framed structure with a corrugated steel skin. This enclosure contained two additional test cells, each large enough to hold a fully assembled propellant feed system.

---

[94] "Testing a Titan," Astronautics 4 (August 1959): 93.

The cold flow installation also included extensive facilities for storing and handling the fuel, oxidizer, and pressurizing gases used to power the missiles. In this facility, observed Astronautics magazine, Martin could test "everything connected with propulsion but the rocket engine itself. Propellant tankage and plumbing is reproduced in this lab, and real or simulated propellants are run through the setup under flight pressures and conditions. The only difference from the real thing is the lack of an engine at the business end."[95]

Captive Firings

Once the engines had proven themselves on the battleship stand, they were installed in actual missile stages which were then put through a battery of increasingly complex captive tests. During this phase of the test process, the individual stages were secured to the test stands and fired each time a new subsystem was integrated into the airframe. The first test after each addition was a tentative, short-duration firing. If this firing was successful, the parameters were expanded to test the performance limits of the new subsystem. This portion of the test program was so rigorous that some Martin engineers reportedly feared the missiles were in danger of becoming "war-weary before they ever reach[ed] the launch pad."[96]

Missile Compatibility Firings

Missiles destined for flight were subjected to yet another series of tests at Martin-

---

[95] Ibid., 92.

[96] Russell Hawkes, "Hardened Titan Bases," Aviation Week 72 (18 January 1960): 81.

Denver. These were short "compatibility firings," in which the missiles' first and second stages were erected side by side on the test stand, connected by electrical cables, and fired in a sequence that closely simulated actual flight conditions. During a compatibility firing, sensors attached to the missile captured 225 separate pieces of information, feeding the data to an array of recording devices in the control room. The sensors monitored the operation of every valve, pump, and relay. They collected information on propellant pressures, temperatures, and flow rates. They checked the timing of staging mechanisms and engine ignition squibs, and tested guidance and control systems. When the compatibilty firing was over, said one industry journalist, the missile was "as ready for flight as it can be made."[97]

PROBLEMS

On 6 February 1959 the first Titan missile was launched from the Atlantic Missile Range at Cape Canaveral, Florida. The Rocky Mountain News recorded the event:

> The 90-foot Titan, designed to hurl a hydrogen warhead across the widest ocean, made a determined start at 2:22 p.m. Denver time and forged through a blue rift in the heavily overcast sky. The very fact that it blasted off smoothly meant that the test was at least 90 percent successful, according to sources here.[98]

By the first part of May, Martin had succeeded in launching three more missiles from Florida. At least one industry analyst attributed the Titan's "exceptionally good early

---

[97] "Testing a Titan," Astronautics 4 (August 1959): 93.

[98] "First Mighty Titan Missile Blasts Off on Space Debut," RMN, 7 February, 1959.

record" to the rigorous test regimen that had been followed at Martin-Denver.[99]

But after this promising start, things suddenly began to go awry. During the summer of 1959, the Titan program was plagued by a "succession of accidents, incidents and . . . failures" on both the test stands and the launch pad. Greatly alarmed by this string of setbacks, the Air Force sent a team of experts to Denver to investigate. Concluding that the problems had been caused by unqualified test crews and a "serious lack of discipline . . . at the test site," the investigators recommended a "complete and immediate suspension of test operations at Denver."[100]

Martin executives immediately flew to Los Angeles to meet with Air Force officials. After promising to hire an experienced test crew and revamp its test procedures, the company was given permission to continue testing. Despite these efforts, the problems persisted, reaching a spectacular climax on 12 December when a Titan exploded on the launch pad at Cape Canaveral in front of scores of reporters from the national media. In a scathing article written two weeks later, Time magazine pointed out that of the approximately three dozen Titans produced up to that time, "five have been lost in accidents, another nine have been damaged, and of the nine, only two of the birds could be put back into flight condition." Noting that the accidents "did not result from any basic flaw" in the missile's design, the magazine laid the blame for the mishaps squarely on the shoulders of Martin's

---

[99] "Testing a Titan," Astronautics 4 (August 1959): 26.

[100] Warren E. Greene, "Development of the SM-68 Titan, Volume 1." (Norton AFB, CA: Historical Office Deputy Commander for Aerospace Systems, 1962), 93. TMs [photocopy]. HRA K243.012-7.

top management, citing the "confusion," "red tape," and "poor morale" that prevailed at the Denver plant.[101]

At the end of December, Martin Board Chairman George M. Bunker announced that he would move to Denver immediately "to take personal charge of the company's Titan ICBM program and revamp the whole operation."[102] He had good reason to be concerned. The Titan program accounted for approximately 25 percent of the Martin Company's annual sales, and it was in serious danger of being cancelled.

Critics of the program contended that the Titan had become superfluous. After all, the first-generation Atlas missile had recently become operational, and an advanced, solid-fueled ICBM called the Minuteman was already in development. But proponents of the program argued that the Titan, with its more reliable propulsion system, longer range, and greater payload capacity, promised to provide a significant performance advantage over the Atlas almost immediately. The Minuteman, by contrast, was still years away from production.[103]

In the end, the Titan's fate may have been decided by economics. As Business Week

[101] "Titan's Troubles," Time 75 (4 January 1960): 64.

[102] Ibid.

[103] The Titan program had been in serious jeopardy at least once before. During the spring of 1957, Secretary of Defense Charles Wilson had approved a drastic cutback in Titan production as part of an effort to reduce defense spending. On 4 October of that year, however, the Soviet Union announced that it had used an ICBM to launch an artificial satellite called "Sputnik." This unexpected demonstration of Soviet technical prowess spawned fears that the Russians had opened up a "missile gap" that gave them a significant lead in the arms race. In an attempt to close this gap, the Defense Department quickly brought the Titan program back to full strength. For an overview of the events of this period, see Roy Licklider, "The Missile Gap Controversy," Political Science Quarterly 85 (December 1970): 600-15. For a discussion of the missile gap's effects on the Titan program, see Alfred Rockefeller, "History of Titan," 14-15; and Jacob Neufeld, Development of Ballistic Missiles, 165 ff.

pointed out at the time, the Titan project had reached the stage where "it would probably be almost as expensive to cancel the program as to continue it. . . . So the outlook is for continuation of the . . . program for the time being -- with the Air Force breathing hard on George Bunker's neck to justify this decision."[104]

Bunker apparently succeeded. On 2 February 1960, a Martin test crew launched yet another R & D Titan from Cape Canaveral, and this time the missile performed flawlessly -- flying more than 2,000 miles and delivering its nosecone to within three miles of its intended target. The situation continued to improve slowly throughout the spring, and by June, most of the objectives of the Titan test program had been accomplished. Reflecting on this period a few years later, Air Force historian Warren Greene concluded that "when all was said and done, in spite of the spectacular failures, the Titan had established the best flight test record of any ballistic missile tested at the Atlantic Missile Range."[105]

DEPLOYMENT

On 16 September 1960, the first fully operational Titan I missile rolled off the assembly line at Martin's Denver plant. The missile was unveiled amid great fanfare at a ceremony attended by thousands of Martin employees, dozens of media representatives, and a host of dignitaries, including Air Force officials, two U.S. Senators, and the director of the Denver Public Works Department, who was standing in for the mayor.

---

[104] "Martin Girds for Titan Crisis," Business Week, 9 January 1960, 71.

[105] Greene, "Development of the SM-68 Titan," 100.

Martin Vice-president William L. Whitson presided over the festivities. In an unfortunate fit of nostalgia, Whitson christened the first Titan the V-2. Then he contrasted it with its historic namesake, noting that the new missile would have 30 times the range and "several million" times the destructive capability of its Nazi predecessor. But according to Whitson, the most important difference was this:

> The German V-2 flew to kill and defeat an enemy. Titan's strength is greatest if it never flies; its strength is greatest if it remains on guard in its . . . base as a deterrent to war until lasting peace is achieved in the World.[106]

After the ceremony, the new V-2 was taken to Vandenberg Air Force Base for flight testing. But before the missile took to the air, it was lowered into a steel and concrete silo set deep into the ground. This silo was the prototype for the blast-resistant launchers that would be installed at the Titan operational sites.

According to Jacob Neufeld, the idea of basing strategic missiles below ground had been born in the early days of the Atlas program:

> In March 1955, [the Western Development Division] adopted some basic operational concepts for the Atlas: the missile would be sited inside fixed, underground facilities; it was to have a quick launch reaction; it was to be stored in a launching position; the launch site would require minimal support; and the launch units were to be self-supporting for two weeks.[107]

---

[106] "Martin's Denver Family Bids Fond 'Adios' to First Operational Titan ICBM," Martin Mercury 18 (11 November 1960): 4.

[107] Neufeld, Development of Ballistic Missiles, 176. According to Neufeld, the underground basing concept was not actually implemented until quite late in the Atlas program: "Rushed into service to head off the so-called missile gap, the Atlas D series was the first operational ICBM deployed. The Atlas Ds were initially located on above-ground, gantry-type launch pads at Vandenberg AFB. Subsequently, the missiles were placed into unprotected "coffins" which also were located above ground. The coffins simplified maintenance but offered no additional hardness. The missiles still had to be fueled and raised into a vertical position for firing. . . . The Atlas E missiles also were placed into coffins, but were covered with earth that was said to provide the missiles with 25

The Titan basing configuration was essentially a refinement of this idea. Each Titan base would have a total of nine missiles, deployed in three dispersed complexes. Each complex would consist of three missile silos controlled by a single launch center. To prevent exhaust gases trapped inside the silos from damaging the missiles during the launch process, the Titans would be mounted atop elevators and lifted out of the ground for firing. The launch center and silos at each site would be "hardened" with layers of steel and concrete, enabling them to withstand blast pressures of 100 pounds per square inch:

> The key objective in hardening the Titan installations was to provide protection in such a manner that any enemy surprise attack could not knock out more than a few of the missiles, and the remainder would always be poised for retaliatory attack. In this situation, hardened Titan sites would present a constant deterrent against enemy attack.[108]

In April 1959, construction began on the first operational site at Lowry AFB, Colorado. The installation was built by a team of civilian contractors, working under the supervision of a newly created division of the U.S. Army Corps of Engineers. The project was a mammoth undertaking that started with the removal of more than two million cubic yards of overburden, including approximately half a million cubic yards of solid rock. After the excavation was completed, the silos and launch centers were built by conventional construction methods. Then the entire complex was reburied beneath at least 20 feet of

---

pounds per square inch protection against overpressures. . . . The most advanced series were the Atlas Fs. At first the Fs sat atop elevators housed inside underground concrete and steel silos. Covered by massive doors, these silos were designed to survive 100 pounds per square inch overpressures." See Neufeld, 192. For a description of the various Atlas basing concepts, see "Atlas ICBM Geared to Total Deployment," Aviation Week and Space Technology 75 (25 September 1961): 143, 145, 147, 149. According to Neufeld, the silo-based Atlas F-series missiles were not activated until September 1962, nearly five months after the first Titan silos became operational.

[108] Alfred Rockefeller, "History of Titan," 15-16.

earth, a fact that led one engineering writer to conclude that "in the the event of a missile attack, Lowry's underground fortresses could well be the safest places on earth."[109]

By the spring of 1962, the Lowry site was ready. On 18 April of that year, General Bernard A. Schriever stepped onto a temporary platform set up on the rolling plains about 25 miles east of downtown Denver. Framed by three tall Titan missiles that had been elevated to ground level just for the occasion, he handed a symbolic key to General Thomas A. Power of the Strategic Air Command. With this simple action, Schriever put the nation's first Titan base on the firing line. Its nine enormous ICBMs were "cocked and ready to be aimed at targets in Russia."[110]

During the next six months, the Air Force activated five additional Titan bases. In addition to a second installation at Lowry, there were new squadrons at Mountain Home AFB, near Mountain Home, Idaho; Larson AFB, near Moses Lake, Washington; Beale AFB, near Sacramento, California; and Ellsworth AFB, near Rapid City, South Dakota. The Denver Post later described these installations in detail:

> A typical Titan site consisted of three dispersed missile silos, each flanked by two smaller silos leading to rocket fuel and liquefied gas storage tanks; two huge dome-shaped bunkers, one a powerhouse 124 feet in diameter and 90 feet high, the other a control center and living quarters for the 11-man crew on duty at all times; plus two other silos which housed tall guidance control antennae. . . . All these were interconnected by 9 1/2-foot-high tunnels along

---

[109] "The Titan ICBM Base: Building from the Ground Down," Engineering News-Record 163 (10 September 1959): 34. For another account of the construction process, see Robert W. Fritz, "Titan Construction for the Titan Missile," Civil Engineering 31 (April 1961): 50-53.

[110] "Titans on Firing Line: New Muscle for U.S.," U. S. News and World Report 52 (30 April 1962): 68. For a detailed description of the activation ceremony, see "SAC Accepts First Titan I Squadron," Martin News (27 April 1962): 1.

> which ran piping and wiring for rocket fuel, . . . power lines, hot and cold water, . . . sewage lines, firefighting system and control and comunication networks. Missilemen could zip along the tunnels on small electric trucks. The entire network was heated and air conditioned with temperature, humidity and air quality carefully controlled. The complexes were self-contained so that crews could survive six months underground. . . . This entire, independent, small city was buried 30 to 60 feet under the prairie with its entries protected by stout steel and concrete abutments. And everything -- the Titan missiles and their elevators, ponderous pumps and engines, fuel tanks, piping -- was mounted on heavy steel springs or thick rubber pads or was protected by flexible couplings. The nuclear age fort could take all but a direct hit by a 10-megaton . . . bomb, shudder, quake and sway back to normal, then deliver its retaliatory punch at targets half a world away.[111]

But by time the last operational Titan was installed in its silo in September of 1962, the Martin Company had already started to test the missile that would make it obsolete.

TITAN II

In May 1960, the Air Force had awarded Martin a new contract to develop an advanced version of the Titan. To be called Titan II, the new missile would constitute "a major design changeover."[112] Missiles and Rockets reporter James Baar explained how the new contract came about:

> The division of the [Titan] program into two distinct missiles is a sharp break with the step-by-step manner in which Atlas was developed. Because of the pressure on the Atlas program, improvements generally were introduced into the production line as quickly as posible. This was not done with Titan. Instead, a cut-off point was established for the introduction of further modifications into Titan I, and these were collected for introduction into Titan II. The result is that Titan II is for all practical purposes a second-generation

---

[111] Mark Bearwald, "Requiem for the Titan," Denver Post Empire, 26 February 1967.

[112] "ICBM Speedup Brings U.S. Gain in Missile Race," Business Week, 2 July 1960, 19.

missile.[113]

By September, the new missile's specifications had been finalized. Although Titan II would use essentially the same structural system as Titan I, the new model stood nearly ten feet taller than its predecessor, and the diameter of its second stage was increased from eight to ten feet. These changes in the size of the airframe greatly expanded Titan II's propellant carrying capacity. The new missile was also designed to be much more powerful than the older one, with engines capable of developing nearly 50 percent more thrust. Furthermore, the advanced Titan was to be equipped with an unjammable, all-inertial guidance system that required no ground-station support. These modifications were intended to increase Titan II's range, improve its accuracy, and enable the missile to carry "a warhead of at least ten megatons energy -- the biggest that can . . . be carried by any U.S. missile."[114]

But the most important differences between Titan II and its antecedent were found in the new missile's propellant system:

> What makes Titan II unique is a storable fuel that requires no LOX (liquid oxygen) and enables the missile to be ready to fire at a moment's notice. LOX, which is used in the Atlas and Titan I, is [a] cheap and efficient oxidizer, but its extreme cold and its eagerness to boil away make it troublesome and unreliable. Instead of this chemical bad actor, Titan II uses nitrogen tetroxide as an oxidizer and a mixture of hydrazine and UDMH

[113] James Baar, "SAC Getting ICBM 'Crusher,'" Missiles and Rockets 7 (5 September 1960): 11.

[114] "Triumphant Titan II," Time 79 (30 March 1962): 68. Also see Frank McGuire, "Titan II Will Get More Range and Payload in Production Line Modification," and "Parts Reduced in Titan II Engine," both included in "Titan: Special Report," Missiles and Rockets 7 (5 September 1960): 24-27. Titan II's increased payload capacity also made it an ideal launch vehicle for the nation's fledgling space program. Between April 1964 and November 1966, modified Titan II missiles launched twelve Gemini space capsules, ten of which were manned. See John H. Berkshire, "Titan II Missile Synopsis," 10 August 1965, V. TMs [photocopy]. Collection of Lt. Col. Daniel Dansro, Ballistic Missile Organization Headquarters, Norton AFB, CA.

> (unsymmetrical dimethylhydrazine) as fuel. Both are liquids that can be stored for long periods at ordinary temperatures in the missile's own tanks, requir[ing] no last-minute transfusions of rebellious, bubbly LOX.[115]

These storable propellants would give Titan II "virtual push-button operational capabilities" -- allowing the missile to be "serviced in advance and remain launch-ready over extended periods."[116]

During the fall of 1960, Martin personnel began to modify captive test stands D-1 and D-2 to accommodate Titan II. The erectors were rebuilt to accommodate the advanced missile's larger airframe. New propellant handling and fire safety equipment was installed at each stand. A second storage tank was built on the hill above the test facilities to provide additional water for cooling the flame deflectors, fighting fires, and washing down the test area in the event of fuel or oxidizer spillages. And the control buildings were fitted with an array of new electronic ground support equipment specifically tailored to the requirements of the new Titan. According to the Martin newsletter, the new control room equipment was "less elaborate than before," because Titan II was so much "less complex" than Titan I.[117]

Martin started battleship tests for the new missile on stand D-1 during the first week

---

[115] "Triumphant Titan II," Time 79 (30 March 1962): 68. The new propellant combination was "hypergolic," meaning that the fuel and oxidizer ignited spontaneously upon contact. This characteristic eliminated the need for a separate ignition system, and made it much easier to start the missile's second stage engine in space.

[116] "First Titan II Propulsion System Test Firing at M-D," Martin Mercury 18 (16 June 1961): O.

[117] The beginning of the conversion program is chronicled in "Test Stand Conversion Efforts Highlighting Test Area Activity," Martin Mercury 18 (11 November 1960): A. For a detailed description of the changes, see "First Titan II Propulsion System Test Firing at M-D," Martin Mercury 18 (16 June 1961): O.

of June 1961.[118] Less than ten months later, the first Titan II was ready for flight testing. Time magazine described its successful debut:

> Confidence surged last week through the U.S. missile program, which suddenly had a new hero: the Titan II, a radically new missile that moves the U.S. a giant step forward in . . . nuclear effectiveness. Resigned to a series of test failures before they get a success, U.S. missilemen were jubilant when the giant Titan II climbed off its pad at Cape Canaveral on the very first try, lit its second stage exactly on schedule and flew a flawless course to the target 5,000 miles away. No big liquid-fuel rocket has ever scored such an immediate triumph.[119]

The Air Force had started to build operational facilities for the Titan IIs long before it had any missiles to put into them. Groundbreaking for the first Titan II site at Davis-Monthan AFB, near Tuscon, Arizona, took place on 9 December 1960. During the next six weeks, work began on additional installations at McConnell AFB, near Wichita, Kansas, and Little Rock AFB, near Little Rock, Arkansas. Two Titan II squadrons were eventually headquartered at each Air Force base. Every squadron consisted of nine dispersed, hardened silos, each served by its own launch control center. This configuration was intended to "present . . . a potential enemy [with] nine separate targets instead of three targets in each complex of Titan I."[120] The missiles waited below ground with a full load of propellants. Ductlike flame deflectors at the bottom of each launch tube permitted firing directly from the silos.

---

[118] According to the Martin News, the last Titan II test firing at Martin Denver took place in June 1964. See "Feb. 6, 1956-Feb. 6, 1966 -- Martin's First Decade in Denver," Martin News (11 February 1966).

[119] "Triumphant Titan II," Time 79 (30 March 1962): 68.

[120] "Titan II to Give USAF Well-Protected Fast-Reaction Strike Force," Aviation Week and Space Technology 75 (25 September 1961): 139.

By the end of December, 1963, construction had been completed at all six Titan II operational sites. A week later U.S. News and World Report announced that "America's mightiest war missile -- the Titan II -- is now on the firing line . . . carrying the most potent warhead in the U.S. arsenal."[121]

PHASING OUT

In late January 1964, Secretary of Defense Robert McNamara informed the House Armed Services Committee that the nation's six Titan I operational bases would be shut down during the 1965 fiscal year. In making his announcement, McNamara noted that, with the advent of the solid-fueled Minuteman ICBM, "the need for these slow reacting and more highly vulnerable older missiles is declining. Their contribution to the planned force will no longer be worth their very high cost of operation and maintenance, estimated at about $1 million per year per missile, compared with only about $100,000 per year for Minuteman."[122]

On 15 April 1964, assembly line workers at Martin-Denver completed production on the last Titan I missile. During the next nine months, the missiles at Beale, Larson, and Ellsworth Air Force Bases were taken off alert. By 1 April 1965, the nation's entire Titan I

[121] "790 U.S. Missiles Ready for Action," U.S News and World Report 56 (6 January 1964): 4.

[122] Quoted in Dan Partner, "Titan I Base Shutdown Slated," DP, 29 January 1964.

force had been removed from active duty.[123] The Denver Post needed only a single paragraph to summarize the missile's brief tenure as the nation's ultimate weapon:

> About five years ago, great gleaming Titan intercontinental missiles were stood on their tails and gently lowered into concrete silos sunk deep into the rolling dry prairies east of Denver. These dreaded symbols of American nuclear power -- shining, complex, deadly bolts of man-made thunder -- were fussed over and maintained by elite Air Force technicians whose bases and barracks were steel and concrete honeycombs 60 feet underground. Today, all but a few of those Titans, their white-painted nuclear stingers pulled, are headed for the scrap heap. The massive installations that once housed them are as obsolete as the Maginot Line.[124]

TITAN II PHASE OUT

The nation's 54 Titan II missiles served a substantially longer tour of duty -- remaining an integral part of the American deterrent force for more than two decades. But they, too, had to be constantly "fussed over and maintained." Within a month of their initial activation, several Titan II missiles at McConnell and Little Rock Air Force bases developed pinhole leaks in their oxidizer tanks. Escaping nitrogen tetroxide combined with moisture in the atmosphere to form nitric acid, which quickly corroded the missiles' aluminum skins.[125] Despite a vigilant program of preventative maintenance, the operational sites continued to be

---

[123] The end of Titan I manufacture was noted by the Rocky Mountain News. See "1964 Marked Transition Period at Martin-Denver," RMN, 2 January 1965. For a concise chronology of each Titan I squadron, see Neufeld, Development of the Ballistic Missile, 236. According to Neufeld, the Titan Is were initially stockpiled at Mira Loma Air Force Station, near Vandenberg AFB, California. But "there was no demand for surplus Titan I missiles . . . and in the Spring of 1966, the Aerospace Corporation [a division of Ramo-Wooldridge] advised against their continued storage." See Neufeld, 238.

[124] Mark Bearwald, "Requiem for the Titans," Denver Post Empire, 26 February 1967.

[125] Colonel A. Kaufman and S. R. Costanza, "Titan II Dehumidification Silo Prevents Missile Leaks," Air Force Civil Engineer 6 (August 1965): 24.

plagued by frequent and often serious mishaps. By 1980, there had been so many accidents that some people living near the silos "were convinced that the Titan II missiles that are supposed to help them sleep better at night pose more dangers to them than to the Russians."[126]

Meanwhile, American military planners had deployed a thousand Minuteman missiles across the nation's heartland. These simple, mass-produced, solid-fueled ICBMs were relatively inexpensive and easy to maintain. "With Minuteman," wrote one observer, "the thing sits in a hole, unattended. When you need it, you hit the button and away she goes."[127] The Minutemen made their liquid-fueled ancestors seem hopelessly obsolete.

The final blow for the Titan program came on 19 September 1980, when a Titan II exploded in its silo near Damascus, Arkansas, flinging its nine-megaton thermonuclear warhead into a nearby field. Following that incident, Time magazine described the aging Titans as "geriatric giants," and hinted that it might be time for them to retire.[128] A number of prominent politicians concurred. A year after the accident, on 2 October 1981, Deputy Secretary of Defense Frank Carlucci ordered the Air Force to begin phasing out the Titan II weapon system "as soon as possible." [129]

On 2 July 1982, the missile at Site 9 in the 570th Strategic Missile Squadron at

---

[126] "Titan a Big Threat -- But to Whom?" U.S. News and World Report 89 (29 September 1980): 8.

[127] Bearwald, "Requiem for the Titans," DP, 26 February 1967.

[128] "Geriatric Giants," Time 116 (6 October 1980): 29.

[129] SAC Missile Chronology: 1939-1982 (Offutt AFB, NE: Office of the Historian, HQ Strategic Air Command, 1983), 70.

Davis-Monthan AFB, Arizona, was taken off alert, becoming the first Titan II to be removed from active service.[130] Deactivation of the remaining sites stretched out over five more years. Finally, in mid-August 1987, the Air Force Times reported that the last of the nation's 54 Titan II missiles, "once the backbone of America's strategic deterrence capability," had been pulled from its silo near Little Rock and shipped to Norton AFB, California, for storage. After more than a quarter of a century, the most powerful weapon of the cold war had been put to rest.[131]

[130] Ibid., 71.

[131] Kenneth Glick, "Final Titan II Goes Into Temporary Retirement," Air Force Times, 17 August 1987.

BIBLIOGRAPHY

PUBLISHED SOURCES

Books

Arendt, Hannah. The Origins of Totalitarianism. New York: Harcourt, Brace & World, Incorporated, 1966.

Beard, Edmund. Developing the ICBM: A Study in Bureaucratic Politics. New York: Columbia University Press, 1976.

Blum, John, et al. The National Experience. New York: Harcourt Brace Jovanovich, 1973.

Blackett, P.M.S. Fear, War, and the Bomb. New York: McGraw Hill Book Company, Incorporated, 1948.

Bobbitt, Phillip. Democracy and Deterrence. New York: St. Martin's Press, 1988.

Brodie, Bernard. The Absolute Weapon. New York: Harcourt, Brace and Company, 1946.

Chapman, John. Atlas: The Story of a Missile. New York: Harper and Brothers, 1960.

_____. Denver Aerospace: Our First Quarter Century in Space, 1956-1981. Denver: Martin Marietta, 1986.

Halberstam, David. The Fifties. New York: Villard Books, 1993.

Inglis, Fred. The Cruel Peace. N.p.: Basic Books, 1991.

LaFeber, Walter. America, Russia, and the Cold War, 1945-1975. New York: John Wiley and Sons, Incorporated, 1976.

Kaplan, Fred. Wizards of Armageddon. Stanford, CA: Stanford University Press, 1991.

Lamont, Langston. Day of Trinity. New York: Atheneum, 1965.

Lehman, Milton. This High Man. New York: Pyramid Books, 1970.

Lewis, Peter. The Fifties. London: Cupid Press, 1989.

Loth, Wilifred. The Division of the World, 1941-1955. New York: St. Martin's Press, 1988.

_____. Martin Marietta Denver Aerospace: 30 Years of Progress. Denver: Martin Marietta, 1986.

Neal, Roy. Ace in the Hole. Garden City, NY: Doubleday and Company, 1962.

Neufeld, Jacob. The Development of Ballistic Missiles in the United States Air Force, 1945-1960. Washington, D.C.: Office of Air Force History, 1990.

_____. Origins of the Cold War. Washington, D.C.: United States Institute of Peace, 1991.

_____. SAC Missile Chronology: 1939-1982. Offutt AFB, NE: Office of the Historian, HQ Strategic Air Command, 1983.

Schwiebert, Ernest G. A History of the U.S. Air Force Ballistic Missiles. New York: Frederick A. Praeger, 1965.

Articles

Anderton, David. "AF Tests Rocket Engines in Giant Stands." Aviation Week 59 (31 August 1953): 24-26.

Ashburn, Anderson. "How Convair Assembles the Atlas." American Machinist 104 (11 January 1960): 71-75.

Baar, James. "SAC Getting ICBM 'Crusher.'" Missiles and Rockets 7 (5 September 1960): 11-12.

Bearwald, Mark. "Requiem for the Titans." Denver Post Empire (26 February 1967): 6-8.

"Bird in the Pit." Time 72 (13 October 1958): 21.

Christian, George L. "Martin Denver Integrates Titan Needs." Aviation Week 66 (17 June 1957): 69-70, 73, 75.

"Enter the IBM." Time 64 (6 December 1954): 28-29.

Funk, Ben I. (Brig. General). "Impact of the Ballistic Missile on Industry." Air University Quarterly Review 9 (Summer 1957): 92-107.

Fritz, Robert W. (Lt. Colonel). "Titan Construction for the Titan Missile." Civil Engineering 31 (April 1961): 50-53.

"Geriatric Giants." Time 116 (6 October 1980): 29.

Hall, Edward N. (Colonel). "Air Force Missile Experience." Air University Quarterly Review 9 (Summer 1957): 22-33.

Hawkes, Russell. "Hardened Titan Bases Require Specialized Support." Aviation Week 72 (18 January 1960): 66-67, 69, 71, 77-78, 81, 83.

Hawkes, Russell. "Martin Proposes Improved Titan System." Aviation Week 72 (11 January 1960): 56-57, 59, 61, 63, 65, 67.

"How a Titan Gets Ready to Fly." Business Week, 5 December 1959, 94-96, 99.

"ICBM Speedup Brings U.S. Gain in Missile Race." Business Week, 2 July 1960, 18-20.

Kaufman, A. (Colonel) and S. R. Costanza. "Titan II Dehumidification Silo Prevents Missile Leaks." Air Force Civil Engineer 6 (August 1965): 24-26.

Licklider, Roy. "The Missile Gap Controversy." Political Science Quarterly 85 (December 1979): 600-15.

"Major Titan Subcontractors and Suppliers." Missiles and Rockets 7 (5 September 1960): 40.

"Martin Girds for Titan Crisis." Business Week, 9 January 1960, 69-71.

McGuire, Frank. "Titan II Will Get More Range and Payload in Production Line Modification." Missiles and Rockets 7 (5 September 1960): 24-26.

"Parts Reduced in Titan II Engine." Missiles and Rockets 7 (5 September 1960): 27.

Perry, Robert L. "The Atlas, Thor, and Titan." Technology and Culture 4 (Fall 1963): 466-77.

"Push-Button Defense?" Newsweek 45 (2 May 1955): 27-30.

Ramo, Simon. "ICBM: Giant Step into Space." Astronautics 2 (August 1957): 34-41, 83-84, 86, 88-89.

Roller, Duane, et al. "Notes on the Technical Aspects of Ballistic Missiles." Air University Quarterly Review 9 (Summer 1957): 34-68.

Rosenberg, David Alan. "The Origins of Overkill." International Security 7 (Spring 1983): 3-71.

Schlesinger, Arthur (Junior). "Origins of the Cold War." Foreign Affairs 46 (October 1967): 22-52.

"790 U.S. Missiles Ready for Action." U.S. News and World Report 56 (6 January 1964): 4, 6.

Sherwin, Martin J. "The Atomic Bomb and the Origins of the Cold War: U.S. Atomic-Energy Policy and Diplomacy, 1941-45." American Historical Review 78 (October 1973): 945-68.

Swanke, Edwin A. (Lt. Colonel) and Richard K. Jacobson (Lt. Colonel). "The Ballistic Missile Test Program." Air University Quarterly Review 9 (Summer 1957): 108-120.

Sweeney, Richard. "How Martin Static-Tests Titan ICBM." Aviation Week 70 (25 May 1959): 88-89, 91', 93, 97, 99, 101.

"Testing a Titan." Astronautics 4 (August 1959): 26-28, 92-93.

"Titan a Big Threat -- But to Whom?" U.S. News and World Report 89 (29 September 1980): 8.

[The] Titan ICBM Base: Building from the Ground Down." Engineering News-Record 163 (10 September 1959): 34-38.

"Titan II to Give USAF Well-Protected Fast-Reaction Strike Force." Aviation Week and Space Technology 75 (25 September 1961): 138-39, 41.

"Titans on the Firing Line: New Muscle for U.S." U.S. News and World Report 52 (30 April 1962): 68-70.

"Titan's Troubles." Time 75 (4 January 1960): 64-65.

"Triumphant Titan II." Time 79 (30 March 1962): 68.

Troxler, Paul D. "Space Missile Facilities." The Military Engineer 53 (March-April 1961): 104-106.

Wells, Samuel. "The Origins of Massive Retaliation," Political Science Quarterly 96 (Spring 1981): 31-52.

"X" [George Kennan]. "The Sources of Soviet Conduct." Foreign Affairs 25 (July 1947): 566-582.

Newspapers

Denver Post, various years.

Martin News, various years. The Martin Company newsletter was published under several other titles over the years, including The Martin Mercury and The Martin-Denver Missile.

Rocky Mountain News, various years.

ARCHIVAL SOURCES

Air Force Historical Research Agency, Maxwell AFB, Alabama. Annual reports of the Western Development Division. Air Force Plant Representative Office histories, the Martin Company. Miscellaneous records relating to the Titan Program.

History Office, Ballistic Missile Organization, Norton AFB, California. Miscellaneous records relating to the ICBM program in general and the Titan program in particular.

Martin Marietta Astronautics Group, Photographics Department, Denver, Colorado. Historic black and white and color photographs of the test facilities at Martin Denver.

Martin Marietta Astronautics Group, Plant Engineering Department, Denver, Colorado. Architectural drawings, blueprints and site plans of the test facilities at Martin-Denver.

TRW (Thompson-Ramo-Wooldridge) Technical Library, Norton AFB, California. Summary reports on testing activities at Martin-Denver.

Western History Department, Denver Public Library, Denver, Colorado. Miscellaneous records pertaining to the Martin Company and the Titan program, including a full set of Martin Company newsletters and extensive files of news clippings taken from the Rocky Mountain News and the Denver Post.

INTERVIEWS/ORAL HISTORIES

Dansro, Daniel A. (Lt. Colonel). Officer at Ballistic Missile Organization. Interviewed by John Lauber, 1 July 1993, BMO Headquarters, Norton AFB, California.

Hixenbaugh, Paul. Mechanical engineer at Martin Denver from 1956 until early 1970s. Interviewed by John Lauber, 3 June 1993, Denver, Colorado.

Picker, Don. Chief, Titan IV Design Support Engineering Group, Martin Marietta Astronautics Group, Denver, Colorado. Telephone interviews by John Lauber, 30 August, 17 September, 28 September 1993.

Schriever, Bernard A. (General). Former commander of Western Development Divison. Interviewed by Major Lyn R. Officer and Dr. James C. Hasdorff, 20 June 1973, Washington, D.C. Transcript in collection of Air Force Historical Research Agency, Maxwell AFB, Alabama. See HRA K239.0512-783.